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(54) Title: APPARATUS FOR REPRODUCING SIGNAL FROM MULTI-LAYERED OPTICAL DISK

(57) Abstract: An optical pickup apparatus for shining light on an optical disk having two recording layers and for detecting reflected light from the optical disk includes a light source, an optical system situated on a path of a light beam returning from the optical disk inclusive of light reflected by a first recording layer of the optical disk and light reflected by a second recording layer of the optical disk, the optical system including a light condensing optical unit to turn the returning light beam into a condensing light beam, and a light beam regulating unit to extract from the condensing light beam a partial light beam corresponding to part of a cross section of the condensing light beam, and one or more photo detectors, situated between a position where the light reflected by the first recording layer contained in the partial light beam is condensed and a position where the light reflected by the second recording layer contained in the partial light beam is condensed, the one or more photo detectors having a first photo detecting section to detect the light reflected by the first recording layer and a second photo detecting section to detect the light reflected by the second recording layer.

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DESCRIPTION

APPARATUS FOR REPRODUCING SIGNAL FROM

5 MULTI-LAYERED OPTICAL DISK

Technical Field

The present invention generally relates to optical pickup apparatuses and optical disk apparatuses. The present invention particularly relates to an optical pickup apparatus which shines a light beam on an optical disk having two recording layers to receive reflected light from the optical disk, and also relates to an optical disc apparatus which performs at least reproduction of information from an optical disk having two recording layers among recording, reproducing, and erasing of information.

20 **Background Art**

With the recent development of the digital technology and improvement of data compression technologies, optical disks such as DVDs (digital versatile disks) have been attracting attention as a record medium for recording information such as

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music, movies, photographs, computer software, etc. (hereinafter also referred to as "contents"). As the price of optical disks goes down, optical disc apparatuses that use the optical disks as 5 information recording medium have spread in the market.

The size of information of contents tends to increase year by year, which leads to an expectation for a further increase in the recording 10 capacity of optical disks. As a means to increase the recording capacity of an optical disk, the record layer may be made into a multi-layered structure. Extensive developments are underway with respect to the optical disks having a plurality of 15 recording layers (hereinafter also referred to as multi-layered disks) and also with respect to the optical disc apparatuses for accessing such multi-layered disks.

In the multi-layered disks, a wide gap 20 between the record layers may cause deterioration of a signal reproduced from a selected record layer due to the effect of spherical aberration. There is thus a trend toward the narrowing of gaps between the record layers. As the gaps between the record 25 layers narrow, however, inter-layer crosstalk occurs,

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so that a light beam returning from the multi-layered disk ends up including not only reflected light (hereinafter referred to as signal light) coming from the selected recording layer but also a 5 significant amount of reflected light (hereinafter referred to as aberrant light) coming from other recording layers different from the selected recording layer. The S/N ratio of the reproduced signal may thus deteriorate.

10 In consideration of this, devices have been developed for reducing inter-layer crosstalk at the time of reproduction from a multi-layered disk (e.g., Patent Document 1 through Patent Document 3).

The apparatuses disclosed in Patent Document 1 through Patent Document 3, however, allow signal light and aberrant light to interfere with each other prior to reaching the photo detecting surface of the photo detecting device. This causes fluctuation in the amount of received light with 20 respect to individual photo detecting devices, which may result in a drop in the S/N ratio of the reproduced signal.

[Patent Document 1] Japanese Patent
Application Publication No. 2001-273640

25 [Patent Document 2] Japanese Patent

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Application Publication No. 10-11786

[Patent Document 3] International Patent

Application Publication No. WO96/20473

Accordingly, there is a need for an
5 optical pickup apparatus that can separate reflected
light components from each other with sufficient
precision when the reflected light components come
from two recording layers of an optical disk.

There is another need for an optical disc
10 apparatus which can reproduce information with
sufficient precision when the information is
obtained from an optical disk having two recording
layers.

15 **Disclosure of Invention**

It is a general object of the present
invention to provide an optical pickup apparatus and
an optical disc apparatus that substantially obviate
one or more problems caused by the limitations and
20 disadvantages of the related art.

Features and advantages of the present
invention will be presented in the description which
follows, and in part will become apparent from the
description and the accompanying drawings, or may be
25 learned by practice of the invention according to

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the teachings provided in the description. Objects as well as other features and advantages of the present invention will be realized and attained by an optical pickup apparatus and an optical disc apparatus particularly pointed out in the specification in such full, clear, concise, and exact terms as to enable a person having ordinary skill in the art to practice the invention.

To achieve these and other advantages in accordance with the purpose of the invention, the invention provides an optical pickup apparatus for shining light on an optical disk having two recording layers and for detecting reflected light from the optical disk. The optical disc apparatus includes a light source, an optical system situated on a path of a light beam returning from the optical disk inclusive of light reflected by a first recording layer of the optical disk and light reflected by a second recording layer of the optical disk, the optical system including a light condensing optical unit to turn the returning light beam into a condensing light beam, and a light beam regulating unit to extract from the condensing light beam a partial light beam corresponding to part of a cross section of the condensing light beam, and one

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or more photo detectors, situated between a position where the light reflected by the first recording layer contained in the partial light beam is condensed and a position where the light reflected 5 by the second recording layer contained in the partial light beam is condensed, the one or more photo detectors having a first photo detecting section to detect the light reflected by the first recording layer and a second photo detecting section 10 to detect the light reflected by the second recording layer.

According to at least one of the embodiments, a light beam emitted from the light source is shone on the optical disk having two 15 recording layers (first recording layer and second recording layer), and a returning light beam inclusive of light reflected by the first recording layer and light reflected by the second recording layer enters the light condensing unit. The light 20 condensing unit turns the returning light into a condensing light beam. A partial light beam that is part of the condensing light beam is then detected by one or more photo detectors. The one or more photo detectors is situated between the condensing 25 point of the light reflected by the first recording

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layer contained in the partial light beam and the condensing position of the light reflected by the second recording layer contained in the partial light beam, and have a first photo detecting section 5 to detect the light reflected by the first recording layer and a second photo detecting section to detect the light reflected by the second recording layer. With this provision, the light reflected by the first recording layer and the light reflected by the 10 second recording layer are obtained separately from each other without mutual interference. This achieves highly precise separation of reflected light beams traveling from the two recording layers of the optical disk.

15 According to another aspect of the present invention, the light beam regulating unit is a light splitting unit configured to split the condensing light beam into a plurality of light beams, the partial light beam corresponding to at least one of 20 the plurality of light beams.

According to another aspect of the present invention, the plurality of light beams includes a first light beam and a second light beam, and the one or more photo detectors includes a first photo 25 detector having a photo detecting section to detect

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the light reflected by the first recording layer contained in the first light beam and a photo detection section to detect the light reflected by the second recording layer contained in the first
5 light beam, and a second photo detector having a photo detecting section to detect the light reflected by the first recording layer contained in the second light beam and a photo detection section to detect the light reflected by the second
10 recording layer contained in the second light beam.

According to another aspect of the present invention, the light splitting unit is a light splitting prism.

According to another aspect of the present
15 invention, the light splitting unit is a hologram having a first hologram area and a second hologram area, the first light beam being diffraction created by the first hologram area, and the second light beam being diffraction created by the second
20 hologram area.

According to another aspect of the present invention, the first light beam and the second light beam are diffractions of different orders.

According to another aspect of the present
25 invention, the first hologram area and the second

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hologram area have respective, different lens functions.

According to another aspect of the present invention, the first light beam and the second light
5 beam are diffractions of an identical order.

According to another aspect of the present invention, the light source, the light splitting unit, and the one or more photo detectors are placed in a single housing and configured as a single
10 package.

According to another aspect of the present invention, a drive unit is further provided, configured to drive the light condensing unit in a direction of an optical axis of the light condensing
15 unit.

According to another aspect of the present invention, a drive unit is further provided, configured to drive the one or more photo detectors in a direction of an optical axis in respect of a
20 photo detecting surface of the one or more photo detectors.

According to another aspect of the present invention, an opto-electrical device is further provided, having a refractive index changing in
25 response to an applied voltage, the opto-electrical

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device situated on a path of the condensing light beam traveling from the light condensing unit.

According to another aspect of the present invention, an optical disc apparatus for reproducing information from an optical disk having two recording layers, includes the optical pickup apparatus as described above, a signal obtaining unit configured to obtain a signal from a selected one of the two recording layers of the optical disk in response to an output signal of the optical pickup apparatus, and a reproducing unit configured to reproduce the information based on the signal obtained by the signal obtaining unit.

This optical disc apparatus is provided with the optical pickup apparatus as described above, so that the signal obtaining unit can easily obtain the signal from the selected one of the two recording layers, resulting in the reproducing unit reproducing information recorded in the selected one of the two recording layers with sufficient precision. That is, the reproduction of information from an optical disk having two recording layers is successfully performed with satisfactory precision.

According to another aspect of the present invention, the signal obtaining unit is configured

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to select an output signal inclusive of only the signal from the selected one of the two recording layers among output signals of the optical pickup apparatus.

5 According to another aspect of the present invention, the signal obtaining unit is configured to subtract a signal component corresponding to another one of the two recording layers from the output signal of the optical pickup apparatus.

10 According to another aspect of the present invention, an optical disc apparatus for reproducing information from an optical disk having two recording layers includes the optical pickup apparatus having the drive unit as described above, 15 a drive control unit configured to control the drive unit in response to a signal indicative of which one of the two recording layers is selected for reproduction, a signal selecting unit configured to select an output signal inclusive of only a signal 20 from the selected one of the two recording layers among output signals of the optical pickup apparatus, and a reproducing unit configured to reproduce the information based on the signal obtained by the signal selecting unit.

25 The optical disc apparatus described above

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is provided with the optical pickup apparatus having the drive unit, and the drive control unit controls the drive unit according to which one of the two recording layers is selected for reproduction. This
5 provides for the signal selecting unit to easily select an output signal including only the signal from the selected one of the two recording layers among the output signals of the optical pickup apparatus. As a result, the reproducing unit can
10 reproduce information recorded in the selected one of the two recording layers with sufficient precision. That is, the reproduction of information from an optical disk having two recording layers is successfully performed with satisfactory precision.

15 According to another aspect of the present invention, an optical disc apparatus for reproducing information from an optical disk having two recording layers includes the optical pickup apparatus having the opto-electrical device, a
20 switching unit configured to control the refractive index of the opto-electrical device in response to a signal indicative of which one of the two recording layers is selected for reproduction, a signal selecting unit configured to select an output signal
25 inclusive of only a signal from the selected one of

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the two recording layers among output signals of the optical pickup apparatus, and a reproducing unit configured to reproduce the information based on the signal selected by the signal selecting unit.

5 The optical disc apparatus described above is provided with the optical pickup apparatus having the opto-electrical device, and the switching unit controls the refractive index of the opto-electrical device according to which one of the two recording 10 layers is selected for reproduction. This provides for the signal selecting unit to select an output signal including only the signal from the selected one of the two recording layers among the output signals of the optical pickup apparatus. As a 15 result, the reproducing unit can reproduce information recorded in the selected one of the two recording layers with sufficient precision. That is, the reproduction of information from an optical disk having two recording layers is successfully 20 performed with satisfactory precision.

Brief Description of Drawings

Fig. 1 is a drawing showing a schematic configuration of an optical disc apparatus according 25 to a first embodiment.

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Fig. 2 is a drawing showing an example of the structure of an optical disk.

Fig. 3A is a drawing showing an example of the construction of an optical pickup apparatus.

5 Fig. 3B is a drawing showing an example of the photo detecting surface of a photo detector.

Fig. 4 is a drawing showing an example of the construction of a PU control circuit.

Figs. 5A and 5B are illustrative drawings
10 for explaining signal light and aberrant light,
respectively.

Figs. 6A through 6C are illustrative drawings for explaining the relationship between the position of a photo detector and the condensing
15 points of signal light and aberrant light, the signal light and aberrant light detected by each photo detecting area, and signals output from the respective photo detecting areas, respectively, when the selected recording layer is a recording layer M0.

20 Figs. 7A through 7C are illustrative drawings for explaining the relationship between the position of a photo detector and the condensing points of signal light and aberrant light, the signal light and aberrant light detected by each
25 photo detecting area, and signals output from the

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respective photo detecting areas, respectively, when the selected recording layer is a recording layer M1.

Fig. 8 is a drawing showing an example of the construction of a RF signal detecting circuit.

5 Figs. 9A through 9C are illustrative drawings for explaining the relationship between the position a photo detector and the condensing points of signal light and aberrant light, the signal light and aberrant light detected by each photo detecting 10 area, and signals output from the respective photo detecting areas, respectively, when the position of a condenser lens is not controlled in response to a change of the selected recording layer from the recording layer M0 to the recording layer M1.

15 Fig. 10 is a diagram for explaining the relationships between a CN ratio of a RF signal and the thickness of an intermediate layer.

Fig. 11 is a drawing showing an example of the construction of the optical pickup apparatus 20 according to a second embodiment of the present invention.

Fig. 12 is a block diagram showing an example of the construction of a PU control circuit for use with the optical pickup apparatus of Fig. 11.

25 Figs. 13A through 13C are illustrative

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drawings for explaining the relationship between the position of a photo detector and the condensing points of signal light and aberrant light, the signal light and aberrant light detected by each 5 photo detecting area, and signals output from the respective photo detecting areas, respectively, when the selected recording layer is the recording layer M0 with respect to the optical pickup apparatus of Fig. 11.

10 Figs. 14A through 14C are illustrative drawings for explaining the relationship between the position of a photo detector and the condensing points of signal light and aberrant light, the signal light and aberrant light detected by each 15 photo detecting area, and signals output from the respective photo detecting areas, respectively, when the selected recording layer is the recording layer M1 with respect to the optical pickup apparatus of Fig. 11.

20 Fig. 15 is a drawing showing an example of the construction of the optical pickup apparatus according to a third embodiment of the present invention.

Fig. 16 is a block diagram showing an 25 example of the construction of a PU control circuit

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for use with the optical pickup apparatus of Fig. 15.

Figs. 17A and 17B are illustrative drawings for explaining the relationship between the position of a photo detector and the condensing points of signal light and aberrant light, and the signal light and aberrant light detected by each photo detecting area, respectively, when the selected recording layer is the recording layer M0 with respect to the optical pickup apparatus of Fig. 15.

10 15.

Figs. 18A and 18B are illustrative drawings for explaining the relationship between the position of a photo detector and the condensing points of signal light and aberrant light, and the signal light and aberrant light detected by each photo detecting area, respectively, when the selected recording layer is the recording layer M1 with respect to the optical pickup apparatus of Fig. 15.

15.

20 Fig. 19A is a drawing showing an example of the construction of the optical pickup apparatus according to a fourth embodiment of the present invention.

Fig. 19B is a drawing for explaining a
25 photo detector shown in Fig. 19A.

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Figs. 20A through 20C are illustrative drawings for explaining the relationship between the position of a photo detector and the condensing points of signal light and aberrant light, the 5 signal light and aberrant light detected by each photo detecting area, and signals output from the respective photo detecting areas, respectively, when the selected recording layer is the recording layer M0 with respect to the optical pickup apparatus of 10 Fig. 19A.

Figs. 21A through 21C are illustrative drawings for explaining the relationship between the position of a photo detector and the condensing points of signal light and aberrant light, the 15 signal light and aberrant light detected by each photo detecting area, and signals output from the respective photo detecting areas, respectively, when the selected recording layer is the recording layer M1 with respect to the optical pickup apparatus of 20 Fig. 19A.

Fig. 22 is a block diagram showing an example of the construction of a RF signal detecting circuit for use with the optical pickup apparatus of Fig. 19A.

25 Figs. 23A through 23C are illustrative

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drawings for explaining the relationship between the position a photo detector and the condensing points of signal light and aberrant light, the signal light and aberrant light detected by each photo detecting area, and signals output from the respective photo detecting areas, respectively, when the position of a condenser lens is not controlled in response to a change of the selected recording layer from the recording layer M0 to the recording layer M1 with respect to the optical pickup apparatus of Fig. 19A.

Fig. 24 is a drawing showing an example of a variation of the optical pickup apparatus shown in Fig. 19A.

Fig. 25 is a drawing showing an example of the construction of the optical pickup apparatus according to a fifth embodiment of the present invention.

Fig. 26 is a block diagram showing an example of the construction of a PU control circuit for use with the optical pickup apparatus of Fig. 25.

Figs. 27A through 27C are illustrative drawings for explaining the relationship between the position of a photo detector and the condensing points of signal light and aberrant light, the signal light and aberrant light detected by each

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photo detecting area, and signals output from the respective photo detecting areas, respectively, when the selected recording layer is the recording layer M0 with respect to the optical pickup apparatus of
5 Fig. 25.

Figs. 28A through 28C are illustrative drawings for explaining the relationship between the position of a photo detector and the condensing points of signal light and aberrant light, the
10 signal light and aberrant light detected by each photo detecting area, and signals output from the respective photo detecting areas, respectively, when the selected recording layer is the recording layer M1 with respect to the optical pickup apparatus of
15 Fig. 25.

Fig. 29 is a block diagram showing an example of the construction of a RF signal detecting circuit for use with the optical pickup apparatus of Fig. 25.

20 Fig. 30 is a drawing showing a variation of the RF signal detecting circuit of Fig. 29.

Fig. 31A is a drawing showing an example of the construction of the optical pickup apparatus according to a sixth embodiment of the present
25 invention.

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Fig. 31B is a drawing for explaining a hologram shown in Fig. 31A.

Figs. 32A through 32C are illustrative drawings for explaining the relationship between the
5 position of a photo detector and the condensing points of signal light and aberrant light, the signal light and aberrant light detected by each photo detecting area, and signals output from the respective photo detecting areas, respectively, when
10 the selected recording layer is the recording layer M0 with respect to the optical pickup apparatus of Fig. 31A.

Figs. 33A through 33C are illustrative drawings for explaining the relationship between the
15 position of a photo detector and the condensing points of signal light and aberrant light, the signal light and aberrant light detected by each photo detecting area, and signals output from the respective photo detecting areas, respectively, when
20 the selected recording layer is the recording layer M1 with respect to the optical pickup apparatus of Fig. 31A.

Fig. 34 is a block diagram showing an example of the construction of a RF signal detecting
25 circuit for use with the optical pickup apparatus of

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Fig. 31A.

Figs. 35A through 35C are illustrative drawings for explaining the relationship between the position of a photo detector and the condensing points of signal light and aberrant light, the signal light and aberrant light detected by each photo detecting area, and signals output from the respective photo detecting areas, respectively, when the position of a condenser lens is not controlled in response to a change of the selected recording layer from the recording layer M0 to the recording layer M1 with respect to the optical pickup apparatus of Fig. 31A.

Fig. 36A is a drawing showing an example of the construction of the optical pickup apparatus according to a seventh embodiment of the present invention.

Fig. 36B is a drawing for explaining a hologram shown in Fig. 36A.

Figs. 37A through 37C are illustrative drawings for explaining the relationship between the position of a photo detector and the condensing points of signal light and aberrant light, the signal light and aberrant light detected by each photo detecting area, and signals output from the respective photo detecting areas, respectively, when

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the selected recording layer is the recording layer M0 with respect to the optical pickup apparatus of Fig. 36A.

Figs. 38A through 38C are illustrative
5 drawings for explaining the relationship between the position of a photo detector and the condensing points of signal light and aberrant light, the signal light and aberrant light detected by each photo detecting area, and signals output from the
10 respective photo detecting areas, respectively, when the selected recording layer is the recording layer M1 with respect to the optical pickup apparatus of Fig. 36A.

Fig. 39 is a block diagram showing an
15 example of the construction of a RF signal detecting circuit for use with the optical pickup apparatus of Fig. 36A.

Figs. 40A and 40B are illustrative
drawings for explaining the relationship between the
20 position of a photo detector and the condensing points of signal light and aberrant light, and the signal light and aberrant light detected by each photo detecting area, respectively, when the selected recording layer is the recording layer M0
25 with respect to a variation of the optical pickup

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apparatus of Fig. 36A.

Figs. 41A and 41B are illustrative drawings for explaining the relationship between the position of a photo detector and the condensing points of signal light and aberrant light, and the signal light and aberrant light detected by each photo detecting area, respectively, when the selected recording layer is the recording layer M1 with respect to the variation of the optical pickup apparatus of Fig. 36A.

Best Mode for Carrying Out the Invention

In the following, embodiments of the present invention will be described with reference to the accompanying drawings.

[First Embodiment]

A first embodiment of the present invention will be described with reference to Fig. 1 through Fig. 10. Fig. 1 is a drawing showing a schematic configuration of an optical disc apparatus 20 according to the first embodiment.

The optical disc apparatus 20 shown in Fig. 1 includes a spindle motor 22 for revolving an optical disk 15, an optical pickup apparatus 23, a seek motor 21 for driving the optical pickup

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apparatus 23 in the sledge direction, a laser control circuit 24, an encoder 25, a servo control circuit 26, a reproduced signal processing circuit 28, a buffer RAM 34, a buffer manager 37, an 5 interface 38, a flash memory 39, a CPU 40, and a RAM 41. Arrows shown in Fig. 1 only illustrates the flows of main signals and information items, and are not intended to represent all the connections between the blocks.

10 According to the first embodiment, the optical disc apparatus 20 is designed to conform to an optical disk having two recording layers, for example. That is, the optical disk 15 is a dual-layered disk.

15 Fig. 2 is a drawing showing an example of the structure of the optical disk 15. As shown in Fig. 2, the optical disk 15 includes a substrate L0, a recording layer M0 (first recording layer), an intermediate layer ML, a recording layer M1 (second recording layer), and a substrate L1 in the named 20 order from the side facing the optical pickup apparatus 23. In each recording layer, a track is formed in spiral form, and information is recorded along the track. A translucent film MBO made of 25 silicon, silver, aluminum, etc., is situated between

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the recording layer M0 and the intermediate layer ML. Further, a metal reflective film MB1 made of silver, aluminum, etc., is provided between the recording layer M1 and the substrate L1. As an example, the 5 optical disk 15 is a dual-layered recordable disk, and is designed to be suitable for light having a wavelength of 660 nm like commercially available DVDs.

The optical pickup apparatus 23 focuses 10 laser light on a recording layer (hereinafter referred to as "selected recording layer") selected among the two recording layers of the optical disk 15, and receives a light beam that is reflected light from the optical disk 15. Fig. 3A is a 15 drawing showing an example of the construction of the optical pickup apparatus 23. As shown in Fig. 3A, the optical pickup apparatus 23 includes a light source unit 51, a coupling lens 52, a beam splitter 54, an objective lens 60, a condenser lens 58 20 serving as optical condenser device, a light blocking plate 59, a photo detector PD serving as an optical detector, a condenser lens actuator AC1 serving as a means to drive the condenser lens 58 in the direction of the optical axis, and an objective 25 lens driving system (i.e., focusing actuator AC2 and

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tracking actuator (not shown)) for driving the objective lens 60.

The light source unit 51 is implemented by use of a semiconductor laser LD, which serves as a 5 light source for emitting laser light having a wavelength of 660 nm. According to the first embodiment, the laser light emitted from the light source unit 51 has the maxim strength in the +X direction. On the +X side of the light source unit 10 51 is situated the coupling lens 52, which turns a light beam emitted from the light source unit 51 into parallel light.

The beam splitter 54 is situated on the +X side of the coupling lens 52. The beam splitter 54 15 lets the light beam from the coupling lens 52 pass through, and splits the light beam (returning light beam) reflected by the optical disk 15 to direct it in the -Z direction. On the +X side of the beam splitter 54 is situated the objective lens 60, which 20 condenses the light beam passing through the beam splitter 54 onto the selected recording layer.

The condenser lens 58 is provided on the -Z side of the beam splitter 54, and turns the returning light beam directed in the -Z direction by 25 the beam splitter 54 into a condensing light beam.

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The light blocking plate 59 blocks the condensing light beam from the condenser lens 58 on the +X side of the optical axis of the condenser lens 58. The condensing light beam on the -X side 5 of the optical axis of the condenser lens 58 travels as a detection-purpose light beam (portion of the condensing light beam) toward the photo detecting surface of the photo detector PD.

Fig. 3B is a drawing showing an example of 10 the photo detecting surface of the photo detector PD. As shown in Fig. 3B, the photo detecting surface of the photo detector PD is divided into a photo detecting area DA and a photo detecting area DB by a dividing line BL extending in the direction 15 corresponding to the direction (i.e., tracking direction) perpendicular to the tangent of the track. The photo detecting area DA is further divided into three photo detecting sub-areas Da, Db, and Dc by two dividing lines perpendicular to the dividing 20 line BL. By the same token, the photo detecting area DB is further divided into three photo detecting sub-areas Dd, De, and Df by two dividing lines perpendicular to the dividing line BL. Each 25 photo detecting sub-area generates an optoelectronic conversion signal responsive to the amount of

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received light. The generated optoelectronic conversion signals are supplied to the reproduced signal processing circuit 28.

The focusing actuator AC2 serves to drive 5 by fine pitches the objective lens 60 in the focusing direction that corresponds to the optical axis of the objective lens 60. The tracking actuator (not shown) serves to drive the objective lens 60 by fine pitches in the tracking direction.

With reference to Fig. 1 again, the reproduced signal processing circuit 28 includes an I/V amplifier 28a, a servo signal detecting circuit 28b, a wobble signal detecting circuit 28c, a RF signal detecting circuit 28d, and a decoder 28e.

The I/V amplifier 28a converts the optoelectronic conversion signals from the photo detector PD into voltage signals, and amplifies these signals with a predetermined gain. In this example, the output signal of the I/V amplifier 28a corresponding to the optoelectronic conversion signal from the photo detecting sub-area Da is denoted as Va, the output signal of the I/V amplifier 28a corresponding to the optoelectronic conversion signal from the photo detecting sub-area Db denoted as Vb, and the output signal of the I/V

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amplifier 28a corresponding to the optoelectronic conversion signal from the photo detecting sub-area Dc denoted as Vc. Further, the output signal of the I/V amplifier 28a corresponding to the 5 optoelectronic conversion signal from the photo detecting sub-area Dd is denoted as Vd, the output signal of the I/V amplifier 28a corresponding to the optoelectronic conversion signal from the photo detecting sub-area De denoted as Ve, and the output 10 signal of the I/V amplifier 28a corresponding to the optoelectronic conversion signal from the photo detecting sub-area Df denoted as Vf.

As shown in equation (1) shown below, the signal (denoted as VA) made by adding up the signals 15 Va, Vb, and Vc is the output signal of the I/V amplifier 28a corresponding to the photo detecting area DA. As shown in equation (2) shown below, the signal (denoted as VB) made by adding up the signals Vd, Ve, and Vf is the output signal of the I/V 20 amplifier 28a corresponding to the photo detecting area DB.

$$VA = Va + Vb + Vc \quad (1)$$

$$VB = Vd + Ve + Vf \quad (2)$$

The servo signal detecting circuit 28b 25 detects servo signals such as a focus error signal

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and a track error signal based on the output signals of the I/V amplifier 28a. The servo signals detected in this manner are supplied to the servo control circuit.

5 The wobble signal detecting circuit 28c detects a wobble signal based on the output signals of the I/V amplifier 28a. The RF signal detecting circuit 28d detects a RF signal based on the output signals of the I/V amplifier 28a. The decoder 28e
10 extracts address information and synchronizing signals from the wobble signal. The extracted address information is supplied to the CPU 40, and the extracted synchronizing signals are supplied to the encoder 25. Further, the decoder 28e performs a
15 decoding process and error detection process with respect to the RF signal. Upon finding error, the decoder 28e performs an error correction process, and stores reproduced data in the buffer RAM 34 via the buffer manager 37.

20 The servo control circuit 26 includes a PU control circuit 26a, a seek motor control circuit 26b, and an SP motor control circuit 26c.

Fig. 4 is a drawing showing an example of the construction of the PU control circuit 26a. As
25 shown in Fig. 4, the PU control circuit 26a includes

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a focusing ACT control circuit 261 for generating a signal (hereinafter referred to as a first driving signal for sake of convenience) driving the focusing actuator AC2, a tracking ACT control circuit 263 for 5 generating a signal (hereinafter referred to as a second driving signal for sake of convenience) driving the tracking actuator (not shown), and a condenser lens ACT control circuit 265 for generating a signal (hereinafter referred to as a 10 third driving signal for sake of convenience) driving the condenser lens actuator AC1.

The focusing ACT control circuit 261 generates the first driving signal based on the recording layer signal indicative of the selected 15 recording layer supplied from the CPU 40 such that the position of the objective lens 60 in the focusing direction is set to either the position corresponding to the recording layer M0 (hereinafter referred to as a first lens position) or the 20 position corresponding to the recording layer M1 (hereinafter referred to as a second lens position). This serves to condense the light beam passing through the beam splitter 54 on the selected recording layer. It should be noted that when the 25 objective lens 60 is situated at the second lens

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position, the gap between the objective lens 60 and the optical disk 15 is narrower than when it is situated at the first lens position (see Fig. 5A and Fig. 5B).

5 The focusing ACT control circuit 261
adjusts the first driving signal in response to the
focus error signal such that focus error is
corrected. This achieves focus control.

10 The tracking ACT control circuit 263
generates the second driving signal based on the
track error signal such that track error is
corrected. This achieves tracking control.

15 The condenser lens ACT control circuit 265
generates the third driving signal based on the
recording layer signal from the CPU 40 such that the
position of the condenser lens 58 in the direction
of the optical axis of the condenser lens 58 is set
to either the position corresponding to the
recording layer M0 (hereinafter referred to as a
20 first corresponding position) or the position
corresponding to the recording layer M1 (hereinafter
referred to as a second corresponding position). A
further description will later be given of the first
corresponding position and the second corresponding
25 position.

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With reference to Fig. 1, the seek motor control circuit 26b generates a signal for driving the seek motor 21 in response to instruction from the CPU 40. The driving signal generated in this 5 manner is supplied to the seek motor 21.

The SP motor control circuit 26c generates a signal for driving the spindle motor 22 in response to instruction from the CPU 40. The driving signal generated in this manner is supplied 10 to the spindle motor 22. The SP motor control circuit 26c further adjusts the signal for driving the spindle motor 22 such that the linear velocity (or angular velocity) of the spindle motor 22 is maintained at specified speed during reproduction or 15 recording operation.

The buffer RAM 34 temporarily stores data (record data) to be recorded on the optical disk 15, data (reproduced data) reproduced from the optical disk 15, etc. The input/output of data into/from 20 the buffer RAM 34 is managed by the buffer manager 37.

The encoder 25 retrieves the record data stored in the buffer RAM 34 via the buffer manager 37 in response to instruction from the CPU 40. The 25 encoder 25 modulates the data, adds error correction

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codes, etc., thereby generating a write signal to be supplied to the optical disk 15. The write signal generated in this manner is supplied to the laser control circuit 24.

5 The laser control circuit 24 controls the power of laser light emitted from the semiconductor laser LD. At the time of recording, for example, the laser control circuit 24 generates a signal for driving the semiconductor laser LD based on the 10 conditions for recording the write signal, the characteristics of light emission of the semiconductor laser LD, etc.

 The interface 38 is a two-way communication interface to communicate with a 15 higher-order apparatus 90 (e.g., personal computer), and complies with interface standards such as ATAPI (AT Attachment Packet Interface) and SCSI (Small Computer System Interface). At the time of reproduction, the reproduced data stored in the 20 buffer RAM 34 is supplied on a sector-by-sector basis to the higher-order apparatus 90 via the interface 38. At the time of recording, the record data is supplied from the higher-order apparatus 90 via the interface 38 for storage in the buffer RAM 25 34 via the buffer manager 37.

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The flash memory 39 is structured to include a program area and a data area. The program area of the flash memory 39 stores programs written in such a code as to be decodable by the CPU 40.

5 The data area of the flash memory 39 stores the recoding conditions, the characteristics of light emission of the semiconductor laser LD, etc.

The CPU 40 controls the operations of the individual parts as described above according to the programs stored in the program area of the flash 10 memory 39. The CPU 40 also stores data necessary for control or the like in the RAM 41 and the buffer RAM 34.

In the following, a description will be 15 given of the light beam returning from the optical disk 15.

When the selected recording layer is the recording layer M0, the objective lens 60 is positioned at the first lens position as shown in 20 Fig. 5A serving as a non-limiting example. With this positioning, the light beam emitted from the semiconductor laser LD is condensed on the recording layer M0 by the objective lens 60. The light beam reflected by the translucent film MB0 enters the 25 objective lens 60 as signal light. A light beam

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passing through the translucent film MB0 is reflected by the metal reflective film MB1 to enter the objective lens 60 as aberrant light.

When the selected recording layer is the 5 recording layer M1, the objective lens 60 is positioned at the second lens position as shown in Fig. 5B serving as a non-limiting example. With this positioning, the light beam emitted from the semiconductor laser LD is condensed on the recording 10 layer M1 by the objective lens 60. The light beam reflected by the metal reflective film MB1 enters the objective lens 60 as signal light. A light beam reflected by the translucent film MB0 enters the objective lens 60 as aberrant light.

15 Namely, the returning light beam always includes a light beam (hereinafter also referred to as a first reflected light beam) reflected by the translucent film MB0 and a light beam (hereinafter also referred to as a second reflected light beam) 20 reflected by the metal reflective film MB1, regardless of which one of the recording layers is the selected recording layer. When the selected recording layer is the recording layer M0, the first reflected light beam is the signal light, and the 25 second reflected light beam is the aberrant light.

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When the selected recording layer is the recording layer M1, on the other hand, the second reflected light beam is the signal light, and the first reflected light beam is the aberrant light.

5 Accordingly, the detection-purpose light beam also includes a signal light component and an aberrant light component. The aberrant light component causes a drop in the S/N ratio when the reproduced signal processing circuit 28 detects various signals,

10 so that the signal light component included in the detection-purpose light beam needs to be separated from the aberrant light component.

The translucent film MB0 and the metal reflective film MB1 are spaced apart in the focusing direction. It follows that the point (F1) at which the first reflected light beam condenses does not coincide with the point (F2) at which the second reflected light beam condenses. That is, these points will be spaced apart from each other in the direction of the optical axis of the condenser lens 58. Between the light condensing point (F1) and the light condensing point (F2), the detection-purpose light beam includes only the second reflected light beam on the +X side of the optical axis of the 20 condenser lens 58 and only the first reflected light

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beam on the -X side.

In consideration of this, the photo detector PD is arranged between the light condensing point F1 and the light condensing point F2 at such a 5 position (hereinafter also referred to as separating photo detecting position) that the photo detecting area DA covers the +X side of the optical axis of the condenser lens 58, and the photo detecting area DB covers the -X side. This makes it possible to 10 detect the first reflected light beam and the second reflected light beam separately from each other.

As shown in Figs. 5A and 5B, however, the distance between the objective lens 60 and the optical disk 15 differs between when the selected 15 recording layer is the recording layer M0 and when the selected recording layer is the recording layer M1. Because of this, the light condensing point F1 and the light condensing point F2 vary, depending on whether the selective recording layer is the recording layer M0 or the recording layer M1. In 20 order to place the photo detector PD at the separating photo detecting position regardless of which one of the recording layers is the selected recording layer, the condenser lens ACT control 25 circuit 265 controls the position of the condenser

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lens 58. As shown in Fig. 6A serving as a non-limiting example, the condenser lens 58 is positioned at the first corresponding position such that the photo detector PD is positioned at the 5 separating photo detecting position when the selected recording layer is the recording layer M0. As shown in Fig. 7A serving as a non-limiting example, the condenser lens 58 is positioned at the second corresponding position such that the photo 10 detector PD is positioned at the separating photo detecting position when the selected recording layer is the recording layer M1.

Accordingly, when the selected recording layer is the recording layer M0, the photo detecting 15 area DA of the photo detector PD detects the aberrant light component, and the photo detecting area DB detects the signal light component, as shown in Fig. 6B serving as a non-limiting example. Namely, the signal VA is a signal Sm that is almost 20 entirely comprised of the aberrant light component with almost no signal light component, and signal VB is a signal Sd that is almost entirely comprised of the signal light component with almost no aberrant light component (see Fig. 6C). In Fig. 6C, FE 25 represents the focus error signal.

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On the other hand, when the selected recording layer is the recording layer M1, the photo detecting area DA of the photo detector PD detects the signal light component, and the photo detecting area DB detects the aberrant light component, as shown in Fig. 7B serving as a non-limiting example. Namely, the signal VA is the signal Sd that is almost entirely comprised of the signal light component with almost no aberrant light component, and the signal VB is the signal Sm that is almost entirely comprised of the aberrant light component with almost no signal light component (see Fig. 7C).

Fig. 8 is a drawing showing an example of the construction of the RF signal detecting circuit 28d. As shown in Fig. 8, the RF signal detecting circuit 28d includes a changeover switch 281 that selects either the signal VB or the signal VA in response to the recording layer signal Lsel supplied from the CPU 40, and also includes an operation circuit 282 that obtains an RF signal based on the output signal of the changeover switch 281. The changeover switch 281 selects the signal VB when the selected recording layer is the recording layer M0, and selects the signal VA when the selected recording layer is the recording layer M1. With

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this provision, it is possible to obtain the RF signal with sufficient precision.

The servo signal detecting circuit 28b detects the track error signal based on a differential between the signal Vd and signal Vf of the I/V amplifier 28a when the selected recording layer is the recording layer M0. The servo signal detecting circuit 28b detects the track error signal based on a differential between the signal Va and signal Vc of the I/V amplifier 28a when the selected recording layer is the recording layer M1.

The servo signal detecting circuit 28b detects the focus error signal FE by extracting lower-frequency components of the signal VB when the selected recording layer is the recording layer M0. The servo signal detecting circuit 28b detects the focus error signal FE by extracting lower-frequency components of the signal VA when the selected recording layer is the recording layer M1.

If the position of the condenser lens 58 is not changed when the selected recording layer is changed from the recording layer M0 to the recording layer M1, F1 and F2 end up being positioned behind the photo detector PD (on the -Z side thereof) as shown in Fig. 9A serving as a non-limiting example.

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In this case, as shown in Fig. 9B serving as a non-limiting example, the photo detecting area DB detects the signal light component mixed with the aberrant light component. The aberrant light 5 component and signal light component cannot be separated from each other (see Fig. 9C).

As can be understood from the above description, the optical disc apparatus 20 according to the first embodiment uses the RF signal detecting 10 circuit 28d as a signal selecting means and the decoder 28e as a reproducing means. Further, the condenser lens ACT control circuit 265 serves as a drive controlling means.

According to the optical pickup apparatus 15 23 of the first embodiment as described above, a light beam emitted from the semiconductor laser LD (light source) condenses on the selected recording layer of the optical disk 15 having two recording layers, and a returning light beam inclusive of the 20 light reflected by the recording layer M0 (first recording layer) and the light reflected by the recording layer M1 (second recording layer) is turned into a condensing light beam by the condenser lens 58 (optical condenser device). The light 25 blocking plate 59 blocks approximately half the

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condensing light beam, and the remaining half of the condensing light beam passes by the light blocking plate 59. The condensing light beam (part of the condensing light beam) passing by the light blocking plate 59 includes the light reflected by the recording layer M0 condensing at F1 and the light reflected by the recording layer M1 condensing at F2. The photo detector PD (optical detector) is positioned between F1 and F2, such that the photo detecting area DB detects the light reflected by the recording layer M0, and the photo detecting area DA detects the light reflected by the recording layer M1. As a result, the light reflected by the recording layer M0 and the light reflected by the recording layer M1 can be separated from each other without mutual interference. This makes it possible to separate the reflected light components from the two recording layers of an optical disk with sufficient precision.

Further, the condenser lens actuator AC1 for driving the condenser lens 58 is provided. This provides for the photo detector PD to be positioned between F1 and F2 regardless of which one of the recording layers is selected.

According to the optical disc apparatus of

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the first embodiment, the RF signal detecting circuit 28d selects a signal corresponding to the selected recording layer among the output signals of the optical pickup apparatus 23 so as to detect the 5 RF signal. Since the optical pickup apparatus 23 outputs an optoelectronic conversion signal corresponding to the reflected light from the selected one of the two recording layers with sufficient precision, an S/N ratio can be improved 10 with respect to the RF signal detected by the RF signal detecting circuit 28d. As a result, the decoder 28e can reproduce information recorded in the selected recording layer with sufficient precision. Namely, the reproduction of information 15 from an optical disk having two recording layers can be achieved with satisfactory precision.

As shown in Fig. 10 serving as a non-limiting example, a drop in the CN ratio (i.e., carrier-noise ratio) in the reproduced signal can be 20 reduced compared with the related-art configuration even if the thickness of the intermediate layer ML decreases. Fig. 10 is a drawing showing the measurements of a CN ratio in the reproduced signal that is obtained by reproducing 5T continuous marks.

25 With the provision of the condenser lens

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ACT control circuit 265, the position of the condenser lens 58 is controlled such that the photo detector PD is situated between F1 and F2 regardless which one of the recording layers is selected. No 5 matter which recording layer is selected, therefore, information recorded in the selected recording layer is reproduced with sufficient precision.

[Second Embodiment]

In the following, a description will be 10 given of a second embodiment of the present invention with reference to Fig. 1 through Fig. 14C.

The second embodiment is a variation of the first embodiment. The second embodiment differs from the first embodiment in that, as shown in Fig. 15 11 serving as a non-limiting example, the photo detector PD is driven rather than driving the condenser lens 58 in the optical pickup apparatus 23. Namely, a photo detector actuator AC3, in place of the condenser lens actuator AC1, is provided as a 20 means to drive the photo detector PD in the direction of the optical axis of the photo detecting surface. Consequently, as shown in Fig. 12 serving as a non-limiting example, the PU control circuit 26a includes a PDACT control circuit 267 for 25 generating a signal (hereinafter referred to as a

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fourth drive signal for sake of convenience) for driving the photo detector actuator AC3. The PDACT control circuit 267 is provided in place of the condenser lens ACT control circuit 265. Most other 5 aspects of the construction are the same as in the first embodiment. In the following, a description will be given by focusing attention on the differences between the first embodiment and the second embodiment. The same or substantially same 10 elements as those of the first embodiment are referred to by the same numerals, and a description thereof will be simplified or omitted.

The PDACT control circuit 267 generates the fourth drive signal such as to position the 15 photo detector PD at the separating photo detecting position in response to the recording layer signal supplied from the CPU 40. When the selected recording layer is the recording layer M0, as shown in Fig. 13A serving as a non-limiting example, the 20 photo detector PD is driven in the +Z direction. When the selected recording layer is the recording layer M1, as shown in Fig. 14A serving as a non-limiting example; the photo detector PD is driven in the -Z direction.

25 As a result, when the selected recording

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layer is the recording layer M0, the photo detecting area DA of the photo detector PD detects the aberrant light component, and the photo detecting area DB detects the signal light component in the 5 same manner as in the first embodiment, as shown in Fig. 13B serving as a non-limiting example. Namely, the signal VA is a signal Sm that is almost entirely comprised of the aberrant light component with almost no signal light component, and signal VB is a 10 signal Sd that is almost entirely comprised of the signal light component with almost no aberrant light component (see Fig. 13C).

On the other hand, when the selected recording layer is the recording layer M1, the photo 15 detecting area DA of the photo detector PD detects the signal light component, and the photo detecting area DB detects the aberrant light component in the same manner as in the first embodiment, as shown in Fig. 14B serving as a non-limiting example. Namely, 20 the signal VA is the signal Sd that is almost entirely comprised of the signal light component with almost no aberrant light component, and the signal VB is the signal Sm that is almost entirely comprised of the aberrant light component with almost no signal light component (see Fig. 14C). 25

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The RF signal detecting circuit 28d selects the signal VB to detect the RF signal as in the first embodiment when the selected recording layer is the recording layer M0, and selects the 5 signal VA to detect the RF signal when the selected recording layer is the recording layer M1. Accordingly, as in the first embodiment, the RF signal is successfully obtained with sufficient precision.

10 The servo signal detecting circuit 28b detects the track error signal and the focus error signal FE in the same manner as in the first embodiment.

According to the second embodiment of the 15 optical pickup apparatus as described above, the photo detecting area DB detects the light reflected by the recording layer M0, and the photo detecting area DA detects the light reflected by the recording layer M1. As a result, the light reflected by the 20 recording layer M0 and the light reflected by the recording layer M1 can be separated from each other without mutual interference. This makes it possible to separate the reflected light components from the two recording layers of an optical disk with 25 sufficient precision.

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Further, the provision of the photo detector actuator AC3 for driving the photo detector PD achieves the proper positioning of the photo detector PD between F1 and F2 regardless of which 5 recording layer is selected.

According to the optical disc apparatus of the second embodiment, further, the optical pickup apparatus 23 outputs an optoelectronic conversion signal corresponding to the reflected light from the 10 selected one of the two recording layers with sufficient precision, which makes it possible to reproduce information recorded in the selected recording layer with sufficient precision in the same manner as in the first embodiment. Namely, the 15 reproduction of information from an optical disk having two recording layers can be achieved with satisfactory precision.

Further, the provision of the PDACT control circuit 267 makes it possible to control the 20 position of the photo detector PD at a proper position between F1 and F2 regardless of which recording layer is selected. Accordingly, no matter which recording layer is selected, it is possible to reproduce the information recorded in the selected 25 recording layer with sufficient precision.

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[Third Embodiment]

In the following, a description will be given of a third embodiment with reference to Fig. 15 through Fig. 18B.

5 The third embodiment is a variation of the first embodiment. The third embodiment differs from the first embodiment in that a liquid crystal device pp serving as an opto-electrical device having its refractive index changing in response to an applied
10 voltage is provided between the light blocking plate 59 and the photo detector PD in the optical pickup apparatus 23 as shown in Fig. 15 serving as a non-limiting example, and in that the condenser lens actuator AC1 is not provided. Consequently, as
15 shown in Fig. 16 serving as a non-limiting example, the PU control circuit 26a includes a PP refractive index switching circuit 269 serving as a switching means for generating a voltage signal applied to the liquid crystal device PP. The PP refractive index
20 switching circuit 269 is provided in place of the condenser lens ACT control circuit 265. Most other aspects of the construction are the same as in the first embodiment: In the following, a description will be given by focusing attention on the
25 differences between the first embodiment and the

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third embodiment. The same or substantially same elements as those of the first embodiment are referred to by the same numerals, and a description thereof will be simplified or omitted.

5 The PP refractive index switching circuit 269 generates the voltage signal in response to the recording layer signal supplied from the CPU 40. The voltage signal is generated such that the refractive index of the liquid crystal device PP is
10 set to either a refractive index corresponding to the recording layer M0 (hereinafter referred to as a first refractive index) or a refractive index corresponding to the recording layer M1 (hereinafter referred to as a second refractive index).

15 The refractive index is equal to the first refractive index when the photo detector PD is positioned at the separating photo detecting position in the case of the selected recording layer being the recording layer M0, as shown in Fig. 17A
20 serving as a non-limiting example. The refractive index is equal to the second refractive index when the photo detector PD is positioned at the separating photo detecting position in the case of the selected recording layer being the recording
25 layer M1, as shown in Fig. 18A serving as a non-

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limiting example.

Accordingly, when the selected recording layer is the recording layer M₀, as shown in Fig. 17B serving as a non-limiting example, the photo detecting area DA receives the aberrant light component, and the photo detecting area DB receives the signal light component in the same manner as in the first embodiment.

Further, when the selected recording layer 10 is the recording layer M₁, as shown in Fig. 18B serving as a non-limiting example, the photo detecting area DA receives the signal light component, and the photo detecting area DB receives the aberrant light component in the same manner as 15 in the first embodiment.

The RF signal detecting circuit 28d selects the signal VB to detect the RF signal as in the first embodiment when the selected recording layer is the recording layer M₀, and selects the signal VA to detect the RF signal when the selected recording layer is the recording layer M₁. Accordingly, as in the first embodiment, the RF signal is successfully obtained with sufficient precision.

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detects the track error signal and the focus error signal FE in the same manner as in the first embodiment.

According to the third embodiment of the
5 optical pickup apparatus as described above, the photo detecting area DB detects the light reflected by the recording layer M0, and the photo detecting area DA detects the light reflected by the recording layer M1 in the same manner as in the first
10 embodiment. As a result, the light reflected by the recording layer M0 and the light reflected by the recording layer M1 can be separated from each other without mutual interference. This makes it possible to separate the reflected light components from the
15 two recording layers of an optical disk with sufficient precision.

Further, the provision of the liquid crystal device PP having its refractive index changing in response to the applied voltage achieves
20 the proper positioning of the photo detector PD between F1 and F2 regardless of which recording layer is selected.

According to the optical disc apparatus of the third embodiment, further, the optical pickup apparatus 23 outputs an optoelectronic conversion
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signal corresponding to the reflected light from the selected one of the two recording layers with sufficient precision, which makes it possible to reproduce information recorded in the selected 5 recording layer with sufficient precision in the same manner as in the first embodiment. Namely, the reproduction of information from an optical disk having two recording layers can be achieved with satisfactory precision.

10 Further, the provision of the PP refractive index switching circuit 269 makes it possible to switch the refractive index of the liquid crystal device PP such that the photo detector PD is properly positioned between F1 and F2 15 regardless of which recording layer is selected. Accordingly, no matter which recording layer is selected, it is possible to reproduce the information recorded in the selected recording layer with sufficient precision.

20 The above embodiment has been described with reference to a case in which a liquid crystal device is used as an opto-electrical device. The present invention is not limited to this example, and an optical device based on opto-electrical 25 crystal with a refractive index changing in response

to an applied voltage may be used, for example.

[Fourth Embodiment]

In the following, a description will be given of a fourth embodiment of the present invention with reference to Fig. 19A through Fig. 23C.

The fourth embodiment is a variation of the first embodiment. The fourth embodiment differs from the first embodiment in that a light splitting prism 61 serving as a light splitting device is used in place of the light blocking plate 59, and two photo detectors PD1 and PD2 are used in place of the photo detector PD in the optical pickup apparatus 23, as shown in Fig. 19A serving as a non-limiting example. Most other aspects of the construction are the same as in the first embodiment. In the following, a description will be given by focusing attention on the differences between the first embodiment and the fourth embodiment. The same or substantially same elements as those of the first embodiment are referred to by the same numerals, and a description thereof will be simplified or omitted.

The light splitting prism 61 splits the condensing light beam from the condenser lens 58 into a light beam on the +X side of the optical axis

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of the condenser lens 58 and a light beam on the -X side of the optical axis of the condenser lens 58. The light beam on the -X side of the optical axis of the condenser lens 58 travels as a first detection-
5 purpose light beam (first light beam) towards the photo detecting surface of the photo detector PD1 (first photo detector). The light beam on the +X side of the optical axis of the condenser lens 58 travels as a second detection-purpose light beam
10 (second light beam) towards the photo detecting surface of the photo detector PD2 (second photo detector). The photo detector PD1 is situated on the +X side of the optical axis of the condenser lens 58, and the photo detector PD2 is situated on
15 the -X side of the optical axis of the condenser lens 58. Each photo detector is positioned substantially at the same distance from the light splitting prism 61 as far as the distance in the Z-axis direction is concerned.
20 The photo detecting surface of the photo detector PD1 is divided into a photo detecting area DA and a photo detecting area DB by a dividing line BL1 extending in the direction corresponding to the tangent direction of the track, as shown in Fig. 19B
25 serving as a non-limiting example. The photo

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detecting area DA is further divided into three photo detecting sub-areas Da, Db, and Dc by two dividing lines perpendicular to the dividing line BL1. By the same token, the photo detecting area DB 5 is further divided into three photo detecting sub-areas Dd, De, and Df by two dividing lines perpendicular to the dividing line BL1. Each photo detecting sub-area generates an optoelectronic conversion signal responsive to the amount of 10 received light. The generated optoelectronic conversion signals are supplied to the reproduced signal processing circuit 28.

The photo detecting surface of the photo detector PD2 is divided into a photo detecting area 15 DC and a photo detecting area DD by a dividing line BL2 extending in the direction corresponding to the tangent direction of the track, as shown in Fig. 19B serving as a non-limiting example. The photo detecting area DC is further divided into three 20 photo detecting sub-areas Dg, Dh, and Di by two dividing lines perpendicular to the dividing line BL2. By the same token, the photo detecting area DD is further divided into three photo detecting sub-areas Dj, Dk, and Dl by two dividing lines 25 perpendicular to the dividing line BL2. Each photo

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detecting sub-area generates an optoelectronic conversion signal responsive to the amount of received light. The generated optoelectronic conversion signals are supplied to the reproduced
5 signal processing circuit 28.

The I/V amplifier 28a converts the optoelectronic conversion signal from the photo detector PD1 and the optoelectronic conversion signal from the photo detector PD2 into voltage
10 signals, and amplifies these signals with a predetermined gain.

The output signals of the I/V amplifier 28a corresponding to the optoelectronic conversion signals from the photo detecting sub-areas Da, Db,
15 Dc, Dd, De, and Df of the photo detector PD1 are denoted as Va, Vb, Vc, Vd, Ve, and Vf, respectively. By the same token, the output signals of the I/V amplifier 28a corresponding to the optoelectronic conversion signals from the photo detecting sub-
20 areas Dg, Dh, Di, Dj, Dk, and Dl of the photo detector PD2 are denoted as Vg, Vh, Vi, Vj, Vk, and Vl, respectively.

As shown in equation (3) shown below, the signal (denoted as VC) made by adding up the signals
25 Vg, Vh, and Vi is the output signal of the I/V

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amplifier 28a corresponding to the photo detecting area DC. As shown in equation (4) shown below, the signal (denoted as VD) made by adding up the signals V_j, V_k, and V_l is the output signal of the I/V amplifier 28a corresponding to the photo detecting area DD. It should be noted that the signals VA and VB are represented in the same manner as in the first embodiment by the equations (1) and (2).

$$VC = Vg + Vh + Vi \quad (3)$$

$$10 \quad VD = Vj + Vk + Vl \quad (4)$$

Between the light condensing position (denoted as F₁₁) of the first reflected light beam contained in the first detection-purpose light beam and the light condensing position (denoted as F₂₁) of the second reflected light beam, the first detection-purpose light beam is divided into the first reflected light beam and the second reflected light beam. The photo detector PD1 is positioned at such a position (hereinafter referred to as "first separating photo detecting position") between the light condensing position F₁₁ and the light condensing position F₂₁ that the photo detecting area DA receives the second reflected light beam, and the photo detecting area DB receives the first reflected light beam. This makes it possible to

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detect the first reflected light beam and the second reflected light beam contained in the first detection-purpose light beam separately from each other.

5 Between the light condensing position (denoted as F₁₂) of the first reflected light beam contained in the second detection-purpose light beam and the light condensing position (denoted as F₂₂) of the second reflected light beam, the second
10 detection-purpose light beam is divided into the second reflected light beam and the first reflected light beam. The photo detector PD2 is positioned at such a position (hereinafter referred to as "second separating photo detecting position") between the
15 light condensing position F₁₂ and the light condensing position F₂₂ that the photo detecting area DC receives the first reflected light beam, and the photo detecting area DD receives the second reflected light beam. This makes it possible to
20 detect the first reflected light beam and the second reflected light beam contained in the second detection-purpose light beam separately from each other.

As shown in Fig. 20A serving as a non-
25 limiting example, the condenser lens 58 is

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positioned at the first corresponding position such that the photo detector PD1 is positioned at the first separating photo detecting position and the photo detector PD2 is positioned at the second 5 separating photo detecting position when the selected recording layer is the recording layer M0. As shown in Fig. 21A serving as a non-limiting example, the condenser lens 58 is positioned at the second corresponding position such that the photo 10 detector PD1 is positioned at the first separating photo detecting position and the photo detector PD2 is positioned at the second separating photo detecting position when the selected recording layer is the recording layer M1.

15 When the selected recording layer is the recording layer M0, the photo detecting areas DB and DC receive the signal light components, and the photo detecting areas DA and DD receive the aberrant light components, as shown in Fig. 20B serving as a 20 non-limiting example. Namely, the signals VB and VC are a signal Sd that is almost entirely comprised of the signal light component with almost no aberrant light component, and the signals VA and VD are a signal Sm that is almost entirely comprised of the 25 aberrant light component with almost no signal light

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component (see Fig. 20C).

On the other hand, when the selected recording layer is the recording layer M1, the photo detecting areas DA and DD receive the signal light components, and the photo detecting areas DB and DC receive the aberrant light components, as shown in Fig. 21B serving as a non-limiting example. Namely, the signals VA and VD are a signal Sd that is almost entirely comprised of the signal light component with almost no aberrant light component, and the signals VB and VC are a signal Sm that is almost entirely comprised of the aberrant light component with almost no signal light component (see Fig. 21C).

Fig. 22 is a drawing showing an example of the construction of the RF signal detecting circuit 28d. As shown in Fig. 22, the RF signal detecting circuit 28d includes an adder 283 for adding up the signal VB and the signal VC from the I/V amplifier 28a, an adder 284 for adding up the signal VA and the signal VD from the I/V amplifier 28a, the changeover switch 281 for selecting either the output signal of the adder 283 or the output signal of the adder 284 in response to the recording layer signal Lsel supplied from the CPU 40, and the operation circuit 282 for obtaining an RF signal

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based on the output signal of the changeover switch 281. The changeover switch 281 selects the output signal of the adder 283 when the selected recording layer is the recording layer M0, and selects the 5 output signal of the adder 284 when the selected recording layer is the recording layer M1. Namely, the RF signal is detected based on a signal Vrf expressed by equation (5) in the following when the selected recording layer is the recording layer M0, 10 and is detected based on a signal Vrf expressed by equation (6) in the following when the selected recording layer is the recording layer M1. With this provision, the RF signal is successfully obtained with sufficient precision.

15 $V_{rf}=V_d + V_e + V_f + V_g + V_h + V_i \quad (5)$

$V_{rf}=V_a + V_b + V_c + V_j + V_k + V_l \quad (6)$

The servo signal detecting circuit 28b detects a track error signal based on a signal Vte expressed by equation (7) in the following when the 20 selected recording layer is the recording layer M0, and detects a track error signal based on a signal Vte expressed by equation (8) in the following when the selected recording layer is the recording layer M1.

25 $V_{te}=(V_d - V_f) + (V_g - V_i) \quad (7)$

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$$V_{te} = (V_a - V_c) + (V_j - V_l) \quad (8)$$

The servo signal detecting circuit 28b detects a focus error signal FE based on a signal V_{fe} expressed by equation (9) in the following when 5 the selected recording layer is the recording layer M0, and detects a focus error signal FE based on a signal V_{fe} expressed by equation (10) in the following when the selected recording layer is the recording layer M1. That is, a so-called W-beam-size method is employed for the purpose of detecting 10 a focus error signal FE.

$$V_{fe} = (V_d + V_f - V_e) - (V_g + V_i - V_h) \quad (9)$$

$$V_{fe} = (V_a + V_c - V_b) - (V_j + V_l - V_k) \quad (10)$$

If the position of the condenser lens 58 15 is not changed when the selected recording layer is changed from the recording layer M0 to the recording layer M1, the light condensing positions F_{11} and F_{21} end up being positioned behind the photo detector PD1, and the light condensing positions F_{12} and F_{22} end up being positioned behind the photo detector 20 PD2, as shown in Fig. 23A serving as a non-limiting example. In this case, as shown in Fig. 23B serving as a non-limiting example, the photo detecting areas DB and DC detect the signal light components mixed 25 with the aberrant light components. The aberrant

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light components and signal light components cannot be separated from each other as shown in Fig. 23C serving as a non-limiting example.

According to the optical pickup apparatus 5 23 of the fourth embodiment as described above, a returning light beam from the optical disk 15 is turned by the condenser lens 58 into a condensing light beam, which is then divided by the light splitting prism 61 into the first detection-purpose 10 light beam (first light beam) and the second detection-purpose light beam (second light beam). The first detection-purpose light beam includes the light reflected by the recording layer M0 condensing at F₁₁ and the light reflected by the recording 15 layer M1 condensing at F₂₁. The second detection-purpose light beam includes the light reflected by the recording layer M0 condensing at F₁₂ and the light reflected by the recording layer M1 condensing at F₂₂. The photo detector PD1 (first photo 20 detector) is positioned between F₁₁ and F₂₁, such that the photo detecting area DB detects the light reflected by the recording layer M0, and the photo detecting area DA detects the light reflected by the recording layer M1. The photo detector PD2 (second 25 photo detector) is positioned between F₁₂ and F₂₂,

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such that the photo detecting area DC detects the light reflected by the recording layer M0, and the photo detecting area DD detects the light reflected by the recording layer M1. As a result, the light
5 reflected by the recording layer M0 and the light reflected by the recording layer M1 can be separated from each other without mutual interference. This makes it possible to separate the reflected light components from the two recording layers of an
10 optical disk with sufficient precision.

Further, the condenser lens actuator AC1 for driving the condenser lens 58 is provided. This provides for each photo detector to be positioned between the light condensing position of light
15 reflected by the recording layer M0 and the light condensing position of light reflected by the recording layer M1.

According to the optical disc apparatus of the fourth embodiment, the optical pickup apparatus
20 23 outputs an optoelectronic conversion signal corresponding to the reflected light from the selected one of the two recording layers with sufficient precision, so that information recorded in the selected recording layer can be reproduced
25 with sufficient precision. Namely, the reproduction

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of information from an optical disk having two recording layers can be achieved with satisfactory precision.

With the provision of the condenser lens 5 ACT control circuit 265, further, the position of the condenser lens 58 is controlled such that each photo detector is situated between the light condensing position of light reflected by the recording layer M0 and the light condensing position of light reflected by the recording layer M1 regardless which one of the recording layers is selected. No matter which recording layer is selected, therefore, information recorded in the selected recording layer is reproduced with sufficient precision.

The optical disc apparatus according to the fourth embodiment uses signal light components contained in the first detection-purpose light beam and signal light components contained in the second detection-purpose light beam in the reproduced signal processing circuit 28. Provision is thus made to improve the efficiency of usage of light compared with the first through third embodiments.

If the signal light components contained in the returning light beam are large in the fourth

embodiment, the reproduced signal processing circuit 28 may use only one of the first detection-purpose light beam and the second detection-purpose light beam to detect relevant signals.

5 In the fourth embodiment described above, the servo signal detecting circuit 28b detects the focus error signal FE by extracting lower-frequency components of the signal VB or the signal VC when the selected recording layer is the recording layer 10 M0. The servo signal detecting circuit 28b detects the focus error signal FE by extracting lower-frequency components of the signal VA or signal VD when the selected recording layer is the recording layer M1.

15 Fig. 24 is a drawing showing an example of a variation of the fourth embodiment. As shown in Fig. 24, a light splitting prism 61' may be used in place of the light splitting prism 61. The light splitting prism 61' is configured such that a light beam on the +X side of the optical axis of the condenser lens 58 travels as the first detection-purpose light beam towards the photo detecting surface of the photo detector PD1, and that a light beam on the -X side of the optical axis of the 20 condenser lens 58 travels as the second detection- 25 condenser lens 58 travels as the second detection-

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purpose light beam towards the photo detecting surface of the photo detector PD2.

[Fifth Embodiment]

In the following, a description will be
5 given of a fifth embodiment with reference to Fig.
25 through Fig. 29.

The fifth embodiment is directed to a first variation of the optical pickup apparatus of the fourth embodiment. In the fifth embodiment, the
10 Z-direction distance between the light splitting prism 61 and the photo detector PD1 and the Z-direction distance between the light splitting prism 61 and the photo detector PD2 are set differently, thereby eliminating a need for the condenser lens
15 actuator AC1 as shown in Fig. 25 serving as a non-limiting example.

Fig. 26 is a drawing showing an example of the construction of the PU control circuit 26a. As shown in Fig. 26, the PU control circuit 26a
20 includes only the focusing ACT control circuit 261 and the tracking ACT control circuit 263. Namely, the condenser lens ACT control circuit 265 is not necessary.

As shown in Fig. 27A serving as a non-
25 limiting example, the photo detector PD1 is

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positioned between the light condensing position F_{11} and the light condensing position F_{21} when the selected recording layer is the recording layer M0. As shown in Fig. 28A serving as a non-limiting example, the photo detector PD2 is positioned between the light condensing position F_{12} and the light condensing position F_{22} when the selected recording layer is the recording layer M1.

Accordingly, when the selected recording layer is the recording layer M0, the photo detecting area DA receives the aberrant light component, and the photo detecting area DB receives the signal light component, as shown in Fig. 27B serving as a non-limiting example. Namely, the signal VA is a signal Sm that is almost entirely comprised of the aberrant light component with almost no signal light component, and the signal VB is a signal Sd that is almost entirely comprised of the signal light component with almost no aberrant light component (see Fig. 27C). At this time, the photo detector PD2 is positioned behind the light condensing position F_{12} and the light condensing position F_{22} , the photo detecting area DD detects the signal light component mixed with the aberrant light component.

On the other hand, when the selected

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recording layer is the recording layer M1, the photo detecting area DC receives the aberrant light component, and the photo detecting area DD receives the signal light component, as shown in Fig. 28B 5 serving as a non-limiting example. Namely, the signal VC is a signal Sm that is almost entirely comprised of the aberrant light component with almost no signal light component, and the signal VD is a signal Sd that is almost entirely comprised of 10 the signal light component with almost no aberrant light component (see Fig. 28C). At this time, the photo detector PD1 is positioned behind the light condensing position F1₁ and the light condensing position F2₁, the photo detecting area DB detects 15 the signal light component mixed with the aberrant light component.

Fig. 29 is a drawing showing an example of the construction of the RF signal detecting circuit 28d. As shown in Fig. 29, the RF signal detecting 20 circuit 28d includes the changeover switch 281 for selecting either the signal VB or the signal VD from the I/V amplifier 28a in response to the recording layer signal Lsel supplied from the CPU 40, and further includes the operation circuit 282 for 25 obtaining an RF signal based on the output signal of

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the changeover switch 281. The changeover switch 281 selects the signal VB when the selected recording layer is the recording layer M0, and selects the signal VD when the selected recording 5 layer is the recording layer M1. With this provision, the RF signal is successfully obtained with sufficient precision.

The servo signal detecting circuit 28b detects a track error signal based on a differential 10 between the signal Vd and the signal Vf from the I/V amplifier 28a when the selected recording layer is the recording layer M0. The servo signal detecting circuit 28b detects a track error signal based on a differential between the signal Vj and the signal Vl 15 from the I/V amplifier 28a when the selected recording layer is the recording layer M1.

The servo signal detecting circuit 28b detects the focus error signal FE by extracting lower-frequency components of the signal VB when the 20 selected recording layer is the recording layer M0. The servo signal detecting circuit 28b further detects the focus error signal FE by extracting lower-frequency components of the signal VD when the selected recording layer is the recording layer M1.

25 According to the fifth embodiment of the

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optical pickup apparatus as described above, the photo detector PD1 (first photo detector) is positioned between F₁₁ and F₂₁ when the selected recording layer is the recording layer M₀, such that
5 the photo detecting area DB detects the light reflected by the recording layer M₀, and the photo detecting area DA detects the light reflected by the recording layer M₁. When the selected recording layer is the recording layer M₁, the photo detector
10 PD2 (second photo detector) is positioned between F₁₂ and F₂₂, such that the photo detecting area DC detects the light reflected by the recording layer M₀, and the photo detecting area DD detects the light reflected by the recording layer M₁. As a
15 result, the light reflected by the recording layer M₀ and the light reflected by the recording layer M₁ can be separated from each other without mutual interference. This makes it possible to separate the reflected light components from the two
20 recording layers of an optical disk with sufficient precision.

According to the optical disc apparatus of the fifth embodiment, the optical pickup apparatus
23 outputs a signal from the selected one of the two
25 recording layers with sufficient precision, so that

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information recorded in the selected recording layer can be reproduced with sufficient precision. Namely, the reproduction of information from an optical disk having two recording layers can be achieved with
5 satisfactory precision.

In the fifth embodiment described above, the RF signal is detected by using the signal VB and signal VD supplied from the I/V amplifier 28a. Alternatively, the signals VA, VB, VC, and VD from
10 the I/V amplifier 28a may be used to detect the RF signal. In this case, the RF signal detecting circuit 28d includes the adder 283 for adding up the signal VB and the signal VD from the I/V amplifier 28a, the adder 284 for adding up the signal VA and
15 the signal VC from the I/V amplifier 28a, a subtraction unit 285 for subtracting the output signal of the adder 284 from the output signal of the adder 283, and the operation circuit 282 for obtaining an RF signal based on the output signal of
20 the subtraction unit 285, as shown in Fig. 30 serving as a non-limiting example. This increases the efficiency of use of light. In this case, the RF signal detecting circuit 28d functions as a signal obtaining unit.

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In the following, a description will be given of a sixth embodiment with reference to Fig. 31A through Fig. 35C.

The sixth embodiment is directed to a
5 second variation of the optical pickup apparatus of the fourth embodiment. The sixth embodiment differs from the fourth embodiment in that a hologram 62 is used in place of the light splitting prism 61, as shown in Fig. 31A serving as a non-limiting example.

10 As shown in Fig. 31B as a non-limiting example, the hologram 62 is divided into two by a dividing line extending in the Y-axis direction. The divided portion on the +X side of the dividing line is a hologram area 62a (first hologram area),
15 and the divided portion on the -X side of the dividing line is a hologram area 62b (second hologram area). As the condensing light beam arrives from the condenser lens 58, the hologram area 62a diffracts the condensing light beam on the
20 +X side of the optical axis of the condenser lens 58, and the hologram area 62b diffracts the condensing light beam on the -X side of the optical axis of the condenser lens 58

The light of +1st order diffraction from
25 the hologram area 62a travels as a first detection-

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purpose light beam (first light beam) towards the photo detecting surface of the photo detector PD1 (first photo detector). The light of -1st order diffraction from the hologram area 62b travels as a
5 second detection-purpose light beam (second light beam) towards the photo detecting surface of the photo detector PD2 (second photo detector). In this manner, the first detection-purpose light beam and the second detection-purpose light beam are light
10 beams of different orders of diffraction.

In the same manner as in the fourth embodiment, the photo detector PD1 is positioned at such a position (first separating photo detecting position) between the light condensing position F₁₁ 15 and the light condensing position F₂₁ that the photo detecting area DA receives the second reflected light beam, and the photo detecting area DB receives the first reflected light beam. This makes it possible to detect the first reflected light beam
20 and the second reflected light beam contained in the first detection-purpose light beam separately from each other. Further, in the same manner as in the fourth embodiment, the photo detector PD2 is positioned at such a position (second separating
25 photo detecting position) between the light

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condensing position F_{12} and the light condensing position F_{22} that the photo detecting area DC receives the first reflected light beam, and the photo detecting area DD receives the second 5 reflected light beam. This makes it possible to detect the first reflected light beam and the second reflected light beam contained in the second detection-purpose light beam separately from each other.

10 As shown in Fig. 32A serving as a non-limiting example, the condenser lens 58 is positioned at the first corresponding position such that the photo detector PD1 is positioned at the first separating photo detecting position and the 15 photo detector PD2 is positioned at the second separating photo detecting position when the selected recording layer is the recording layer M0. As shown in Fig. 33A serving as a non-limiting example, the condenser lens 58 is positioned at the 20 second corresponding position such that the photo detector PD1 is positioned at the first separating photo detecting position and the photo detector PD2 is positioned at the second separating photo detecting position when the selected recording layer 25 is the recording layer M1.

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When the selected recording layer is the recording layer M0, the photo detecting areas DA and DD receive the signal light components, and the photo detecting areas DB and DC receive the aberrant light components, as shown in Fig. 32B serving as a non-limiting example. Namely, the signals VA and VD are a signal Sd that is almost entirely comprised of the signal light component with almost no aberrant light component, and the signals VB and VC are a signal Sm that is almost entirely comprised of the aberrant light component with almost no signal light component (see Fig. 32C).

On the other hand, when the selected recording layer is the recording layer M1, the photo detecting areas DB and DC receive the signal light components, and the photo detecting areas DA and DD receive the aberrant light components, as shown in Fig. 33B serving as a non-limiting example. Namely, the signals VB and VC are a signal Sd that is almost entirely comprised of the signal light component with almost no aberrant light component, and the signals VA and VD are a signal Sm that is almost entirely comprised of the aberrant light component with almost no signal light component (see Fig. 33C).

Fig. 34 is a drawing showing an example of

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the construction of the RF signal detecting circuit 28d. As shown in Fig. 34, the RF signal detecting circuit 28d includes the adder 283 for adding up the signal VA and the signal VD from the I/V amplifier 28a, the adder 284 for adding up the signal VB and the signal VC from the I/V amplifier 28a, the changeover switch 281 for selecting either the output signal of the adder 283 or the output signal of the adder 284 in response to the recording layer signal Lsel supplied from the CPU 40, and the operation circuit 282 for obtaining an RF signal based on the output signal of the changeover switch 281. The changeover switch 281 selects the output signal of the adder 283 when the selected recording layer is the recording layer M0, and selects the output signal of the adder 284 when the selected recording layer is the recording layer M1. Namely, the RF signal is detected based on the signal Vrf expressed by the above-noted equation (6) when the selected recording layer is the recording layer M0, and is detected based on the signal Vrf expressed by the above-noted equation (5) when the selected recording layer is the recording layer M1. With this provision, the RF signal is successfully obtained with sufficient precision.

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The servo signal detecting circuit 28b detects a track error signal based on the signal Vte expressed by the above-noted equation (8) when the selected recording layer is the recording layer M0,
5 and detects a track error signal based on the signal Vte expressed by the above-noted equation (7) when the selected recording layer is the recording layer M1.

The servo signal detecting circuit 28b
10 detects a focus error signal FE based on the signal Vfe expressed by the above-noted equation (10) when the selected recording layer is the recording layer M0, and detects a focus error signal FE based on the signal Vfe expressed by the above-noted equation (9)
15 when the selected recording layer is the recording layer M1.

If the position of the condenser lens 58 is not changed when the selected recording layer is changed from the recording layer M0 to the recording
20 layer M1, the light condensing positions F₁₁ and F₂₁ end up being positioned behind the photo detector PD1, and the light condensing positions F₁₂ and F₂₂ end up being positioned behind the photo detector PD2, as shown in Fig. 35A serving as a non-limiting
25 example. In this case, as shown in Fig. 35B serving

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as a non-limiting example, the photo detecting areas DA and DD detect the signal light components mixed with the aberrant light components. The aberrant light components and signal light components cannot
5 be separated from each other as shown in Fig. 35C serving as a non-limiting example.

According to the optical pickup apparatus of the sixth embodiment as described above, a returning light beam from the optical disk 15 is
10 turned by the condenser lens 58 into a condensing light beam, which is then divided by the hologram 62 into the first detection-purpose light beam (first light beam) and the second detection-purpose light beam (second light beam). The first detection-
15 purpose light beam includes the light reflected by the recording layer M0 condensing at F₁₁ and the light reflected by the recording layer M1 condensing at F₂₁. The second detection-purpose light beam includes the light reflected by the recording layer
20 M0 condensing at F₁₂ and the light reflected by the recording layer M1 condensing at F₂₂. The photo detector PD1 (first photo detector) is positioned between F₁₁ and F₂₁, such that the photo detecting area DB detects the light reflected by the recording
25 layer M0, and the photo detecting area DA detects

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the light reflected by the recording layer M1. The photo detector PD2 (second photo detector) is positioned between F1₂ and F2₂, such that the photo detecting area DC detects the light reflected by the 5 recording layer M0, and the photo detecting area DD detects the light reflected by the recording layer M1. As a result, the light reflected by the recording layer M0 and the light reflected by the recording layer M1 can be separated from each other 10 without mutual interference. This makes it possible to separate the reflected light components from the two recording layers of an optical disk with sufficient precision.

According to the optical disc apparatus of 15 the sixth embodiment, the optical pickup apparatus 23 outputs a signal from the selected one of the two recording layers with sufficient precision, so that information recorded in the selected recording layer can be reproduced with sufficient precision. Namely, 20 the reproduction of information from an optical disk having two recording layers can be achieved with satisfactory precision.

In the sixth embodiment as described above, the photo detector PD1 receives the light of the 25 +1st order diffraction from the hologram area 62a,

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and the photo detector PD2 receives the light of -1st order diffraction from the hologram area 62b. This embodiment is not limited to this example. The photo detector PD1 may receive -1st order diffraction from the hologram area 62a, and the photo detector PD2 may receive the light of +1st order diffraction from the hologram area 62b.

The sixth embodiment has been described with reference to a case in which the semiconductor laser LD, the hologram 62, and each photo detector are arranged separately from each other. Without being limited to this example, the semiconductor laser LD, the hologram 62, and each photo detector may all be placed in the same housing and provided as a single package.

In the sixth embodiment described above, the servo signal detecting circuit 28b detects the focus error signal FE by extracting lower-frequency components of the signal VA or the signal VD when the selected recording layer is the recording layer M0. The servo signal detecting circuit 28b detects the focus error signal FE by extracting lower-frequency components of the signal VB or signal VC when the selected recording layer is the recording layer M1.

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[Seventh Embodiment]

In the following, a description will be given of a seventh embodiment with reference to Fig. 36A through Fig. 39.

5 The seventh embodiment is directed to a variation of the optical pickup apparatus of the sixth embodiment. The seventh embodiment uses a hologram 63 having two areas with different lens functions, which replaces the hologram 62, thereby
10 eliminating a need for the condenser lens actuator AC1 as shown in Fig. 36A serving as a non-limiting example.

As shown in Fig. 36B as a non-limiting example, the hologram 63 is divided into two by a
15 dividing line extending in the Y-axis direction. The divided portion on the +X side of the dividing line is a hologram area 63a (first hologram area), and the divided portion on the -X side of the dividing line is a hologram area 63b (second
20 hologram area). As the condensing light beam arrives from the condenser lens 58, the hologram area 63a diffracts the condensing light beam on the +X side of the optical axis of the condenser lens 58, and the hologram area 63b diffracts the condensing
25 light beam on the -X side of the optical axis of the

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condenser lens 58

The light of +1st order diffraction from the hologram area 63a travels as a first detection-purpose light beam (first light beam) towards the 5 photo detecting surface of the photo detector PD1 (first photo detector). The light of +1st order diffraction from the hologram area 63b travels as a second detection-purpose light beam (second light beam) towards the photo detecting surface of the 10 photo detector PD2 (second photo detector). In this manner, the first detection-purpose light beam and the second detection-purpose light beam are light beams of the same order of diffraction.

In the same manner as in the fourth 15 embodiment, the photo detector PD1 is positioned at such a position (first separating photo detecting position) between the light condensing position F₁₁ and the light condensing position F₂₁ that the photo detecting area DA receives the second reflected 20 light beam, and the photo detecting area DB receives the first reflected light beam. This makes it possible to detect the first reflected light beam and the second reflected light beam contained in the first detection-purpose light beam separately from 25 each other. Further, in the same manner as in the

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fourth embodiment, the photo detector PD2 is positioned at such a position (second separating photo detecting position) between the light condensing position F1₂ and the light condensing 5 position F2₂ that the photo detecting area DC receives the first reflected light beam, and the photo detecting area DD receives the second reflected light beam. This makes it possible to detect the first reflected light beam and the second 10 reflected light beam contained in the second detection-purpose light beam separately from each other.

As shown in Fig. 37A serving as a non-limiting example, when the selected recording layer 15 is the recording layer M0, the lens function of the hologram area 63b is configured such that the photo detector PD2 is situated at such a position between the light condensing position F1₂ and the light condensing position F2₂ that the photo detecting 20 area DD detects the first reflected light beam, and the photo detecting area DC detects the second reflected light beam.

As shown in Fig. 38A serving as a non-limiting example, when the selected recording layer 25 is the recording layer M1, the lens function of the

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hologram area 63a is configured such that the photo detector PD1 is situated at such a position between the light condensing position F₁₁ and the light condensing position F₂₁ that the photo detecting area DA detects the first reflected light beam, and the photo detecting area DB detects the second reflected light beam. Namely, the hologram area 63a and the hologram area 63b have different lens functions.

When the selected recording layer is the recording layer M₀, the photo detecting area DD detects the signal light component, and the photo detecting area DC detects the aberrant light component, as shown in Fig. 37B serving as a non-limiting example. Namely, the signal VD is a signal S_d that is almost entirely comprised of the signal light component with almost no aberrant light component, and the signal VC is a signal S_m that is almost entirely comprised of the aberrant light component with almost no signal light component (see Fig. 37C). At this time, the photo detector PD1 is positioned behind the light condensing position F₁₁ and the light condensing position F₂₁, the photo detecting area DB detects the signal light component mixed with the aberrant light component.

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On the other hand, when the selected recording layer is the recording layer M1, the photo detecting area DB receives the signal light component, and the photo detecting area DA receives 5 the aberrant light components, as shown in Fig. 38B serving as a non-limiting example. Namely, the signal VB is a signal Sd that is almost entirely comprised of the signal light component with almost no aberrant light component, and the signal VA is a 10 signal Sm that is almost entirely comprised of the aberrant light component with almost no signal light component (see Fig. 38C). At this time, the photo detector PD2 is positioned ahead the light condensing position F1₂ and the light condensing 15 position F2₂, the photo detecting area DD detects the signal light component mixed with the aberrant light component.

Fig. 39 is a drawing showing an example of the construction of the RF signal detecting circuit 20 28d. As shown in Fig. 39, the RF signal detecting circuit 28d includes the changeover switch 281 for selecting either the signal VD or the signal VB from the I/V amplifier 28a in response to the recording layer signal Lsel supplied from the CPU 40, and also 25 includes the operation circuit 282 for obtaining an

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RF signal based on the output signal of the changeover switch 281. The changeover switch 281 selects the signal VD when the selected recording layer is the recording layer M0, and selects the 5 signal VB when the selected recording layer is the recording layer M1. With this provision, the RF signal is successfully obtained with sufficient precision.

The servo signal detecting circuit 28b 10 detects a track error signal based on a differential between the signal Vj and signal Vl from the I/V amplifier 28a when the selected recording layer is the recording layer M0, and detects a track error signal based on a differential between the signal Vd 15 and signal Vf from the I/V amplifier 28a when the selected recording layer is the recording layer M1.

The servo signal detecting circuit 28b detects a focus error signal FE by extracting lower-frequency components of the signal VD when the 20 selected recording layer is the recording layer M0. The servo signal detecting circuit 28b detects the focus error signal FE by extracting lower-frequency components of the signal VB when the selected recording layer is the recording layer M1.

25 In the optical pickup apparatus of the

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seventh embodiment as described above, the photo detector PD2 (second photo detector) is positioned between the light condensing position F₁₂ and light condensing position F₂₂ when the selected recording 5 layer is the recording layer M₀ such that the photo detecting area DC detects the reflected light from the recording layer M₁, and the photo detecting area DD detects the reflected light from the recording layer M₀. Further, the photo detector PD1 (first 10 photo detector) is positioned between the light condensing position F₁₁ and light condensing position F₂₁ when the selected recording layer is the recording layer M₁ such that the photo detecting area DA detects the reflected light from the recording 15 layer M₀, and the photo detecting area DB detects the reflected light from the recording layer M₁. This achieves substantially the same results as the optical pickup apparatus of the sixth embodiment.

According to the optical disc apparatus of 20 the seventh embodiment, the optical pickup apparatus 23 outputs a signal from the selected one of the two recording layers with sufficient precision, so that substantially the same results as in the optical pickup apparatus of the sixth embodiment are 25 achieved.

In the seventh embodiment, the RF signal is detected by using the signal VD and signal VB supplied from the I/V amplifier 28a. Alternatively, the signals VA, VB, VC, and VD from the I/V 5 amplifier 28a may be used to detect the RF signal as was described in connection with the fifth embodiment (see Fig. 30). In this case, the RF signal detecting circuit 28d is used as a signal obtaining unit.

10 The seventh embodiment has been described with reference to a case in which the direction of diffraction of the hologram area 63a and the direction of diffraction of the hologram area 63b are opposite to each other in the X-axis direction. 15 Without being limited to this example, the direction of diffraction of the hologram area 63a and the direction of diffraction of the hologram area 63b may be the same in the X-axis direction as shown in Fig. 40A through Fig. 41B, for example.

20 Further, the seventh embodiment has been described with reference to a case in which the semiconductor laser LD, the hologram 63, and each photo detector are arranged separately from each other. Without being limited to this example, the 25 semiconductor laser LD, the hologram 63, and each

photo detector may all be placed in the same housing and provided as a single package.

The above embodiments have been described with reference to a case in which the optical disk 5 15 is designed for light having a wavelength of about 660 nm. The present invention is not limited to this example, and may be used with light having a wavelength of about 780 nm or light having a wavelength of about 405 nm. In such a case, the 10 light source unit 51 emits light having substantially the same wavelength as the light suitable for the optical disk 15.

The above embodiments have been described with reference to a case in which the optical disk 15 15 is recordable. The present invention is not limited to this example, and may be applied to a reproduction-only apparatus.

The above embodiments have been described with reference to a case in which the optical disc 20 apparatus 20 has an information recording function and an information reproducing function. This is not a limiting example, and it suffices to have at least a reproduction function among the functions for recording, reproducing, and erasing of 25 information.

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The above embodiments have been described with reference to a case in which the optical pickup apparatus has a single semiconductor laser. This is not a limiting example, and a plurality of 5 semiconductor lasers for emitting light of respective, different wavelengths may be provided. In this case, the wavelength of a semiconductor laser for emitting light with a wavelength of about 405 nm may include at least one of a semiconductor 10 laser for emitting light with a wavelength of about 660 nm and a semiconductor laser for emitting light with a wavelength of about 780 nm. Namely, the optical disc apparatus may be designed to conform to a plurality of different types of optical disks that 15 comply with respective, different standards. In this case, at least one of the plurality of types of optical disks may be a multi-layered disk.

Further, the present invention is not limited to these embodiments, but various variations 20 and modifications may be made without departing from the scope of the present invention.

The present application is based on Japanese priority application No. 2004-037814 filed on February 16, 2004, with the Japanese Patent 25 Office, the entire contents of which are hereby

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incorporated by reference.

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Claims

1. An optical pickup apparatus for shining light on an optical disk having two recording layers 5 and for detecting reflected light from the optical disk, comprising:

a light source;

an optical system situated on a path of a light beam returning from the optical disk inclusive 10 of light reflected by a first recording layer of the optical disk and light reflected by a second recording layer of the optical disk, said optical system including:

a light condensing optical unit to 15 turn the returning light beam into a condensing light beam; and

a light beam regulating unit to extract from the condensing light beam a partial light beam corresponding to part of a cross section 20 of the condensing light beam; and

one or more photo detectors, situated between a position where the light reflected by the first recording layer contained in the partial light beam is condensed and a position where the light 25 reflected by the second recording layer contained in

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the partial light beam is condensed, said one or more photo detectors having a first photo detecting section to detect the light reflected by the first recording layer and a second photo detecting section 5 to detect the light reflected by the second recording layer.

2. The optical pickup apparatus as claimed in claim 1, wherein said light beam regulating unit 10 is a light splitting unit configured to split the condensing light beam into a plurality of light beams, said partial light beam corresponding to at least one of the plurality of light beams.

15 3. The optical pickup apparatus as claimed in claim 2, wherein the plurality of light beams includes a first light beam and a second light beam, and said one or more photo detectors includes:

a first photo detector having a photo 20 detecting section to detect the light reflected by the first recording layer contained in the first light beam and a photo detection section to detect the light reflected by the second recording layer contained in the first light beam; and

25 a second photo detector having a photo

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detecting section to detect the light reflected by
the first recording layer contained in the second
light beam and a photo detection section to detect
the light reflected by the second recording layer
5 contained in the second light beam.

4. The optical pickup apparatus as claimed
in claim 2, wherein said light splitting unit is a
light splitting prism.

10

5. The optical pickup apparatus as claimed
in claim 2, wherein said light splitting unit is a
hologram having a first hologram area and a second
hologram area, the first light beam being
15 diffraction created by the first hologram area, and
the second light beam being diffraction created by
the second hologram area.

6. The optical pickup apparatus as claimed
20 in claim 5, wherein the first light beam and the
second light beam are diffractions of different
orders.

7. The optical pickup apparatus as claimed
25 in claim 5, wherein the first hologram area and the

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second hologram area have respective, different lens functions.

8. The optical pickup apparatus as claimed
5 in claim 7, wherein the first light beam and the second light beam are diffractions of an identical order.

9. The optical pickup apparatus as claimed
10 in claim 2, wherein said light source, said light splitting unit, and said one or more photo detectors are placed in a single housing and configured as a single package.

15 10. The optical pickup apparatus as claimed in claim 1, further comprising a drive unit configured to drive said light condensing unit in a direction of an optical axis of said light condensing unit.

20

11. The optical pickup apparatus as claimed in claim 1, further comprising a drive unit configured to drive said one or more photo detectors in a direction of an optical axis in respect of a 25 photo detecting surface of said one or more photo

-100-

detectors.

12. The optical pickup apparatus as
claimed in claim 1, further comprising an opto-
5 electrical device having a refractive index changing
in response to an applied voltage, said opto-
electrical device situated on a path of the
condensing light beam traveling from said light
condensing unit.

10

13. An optical disc apparatus for
reproducing information from an optical disk having
two recording layers, comprising:

said optical pickup apparatus of claim 1;
15 a signal obtaining unit configured to
obtain a signal from a selected one of the two
recording layers of the optical disk in response to
an output signal of said optical pickup apparatus;
and

20 a reproducing unit configured to reproduce
the information based on the signal obtained by said
signal obtaining unit.

14. The optical disc apparatus as claimed
25 in claim 13, wherein said signal obtaining unit is

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configured to select an output signal inclusive of only the signal from the selected one of the two recording layers among output signals of said optical pickup apparatus.

5

15. The optical disc apparatus as claimed in claim 13, wherein said signal obtaining unit is configured to subtract a signal component corresponding to another one of the two recording 10 layers from the output signal of the optical pickup apparatus.

16. An optical disc apparatus for reproducing information from an optical disk having 15 two recording layers, comprising:

 said optical pickup apparatus of claim 10;
 a drive control unit configured to control said drive unit in response to a signal indicative of which one of the two recording layers is selected 20 for reproduction;

 a signal selecting unit configured to select an output signal inclusive of only a signal from the selected one of the two recording layers among output signals of said optical pickup 25 apparatus; and

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a reproducing unit configured to reproduce the information based on the signal obtained by said signal selecting unit.

5 17. An optical disc apparatus for reproducing information from an optical disk having two recording layers, comprising:

 said optical pickup apparatus of claim 11;

10 a drive control unit configured to control said drive unit in response to a signal indicative of which one of the two recording layers is selected for reproduction;

15 a signal selecting unit configured to select an output signal inclusive of only a signal from the selected one of the two recording layers among output signals of said optical pickup apparatus; and

20 a reproducing unit configured to reproduce the information based on the signal selected by said signal selecting unit.

18. An optical disc apparatus for reproducing information from an optical disk having two recording layers, comprising:

25 said optical pickup apparatus of claim 12;

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a switching unit configured to control the refractive index of said opto-electrical device in response to a signal indicative of which one of the two recording layers is selected for reproduction;

5 a signal selecting unit configured to select an output signal inclusive of only a signal from the selected one of the two recording layers among output signals of said optical pickup apparatus; and

10 a reproducing unit configured to reproduce the information based on the signal selected by said signal selecting unit.

19. An optical pickup apparatus for
15 shining light on an optical disk having two recording layers and for detecting reflected light from the optical disk, comprising:

20 a light source;
an optical system situated on a path of a light beam returning from the optical disk inclusive of light reflected by a first recording layer of the optical disk and light reflected by a second recording layer of the optical disk, said optical system including:
25 a light condensing optical unit to

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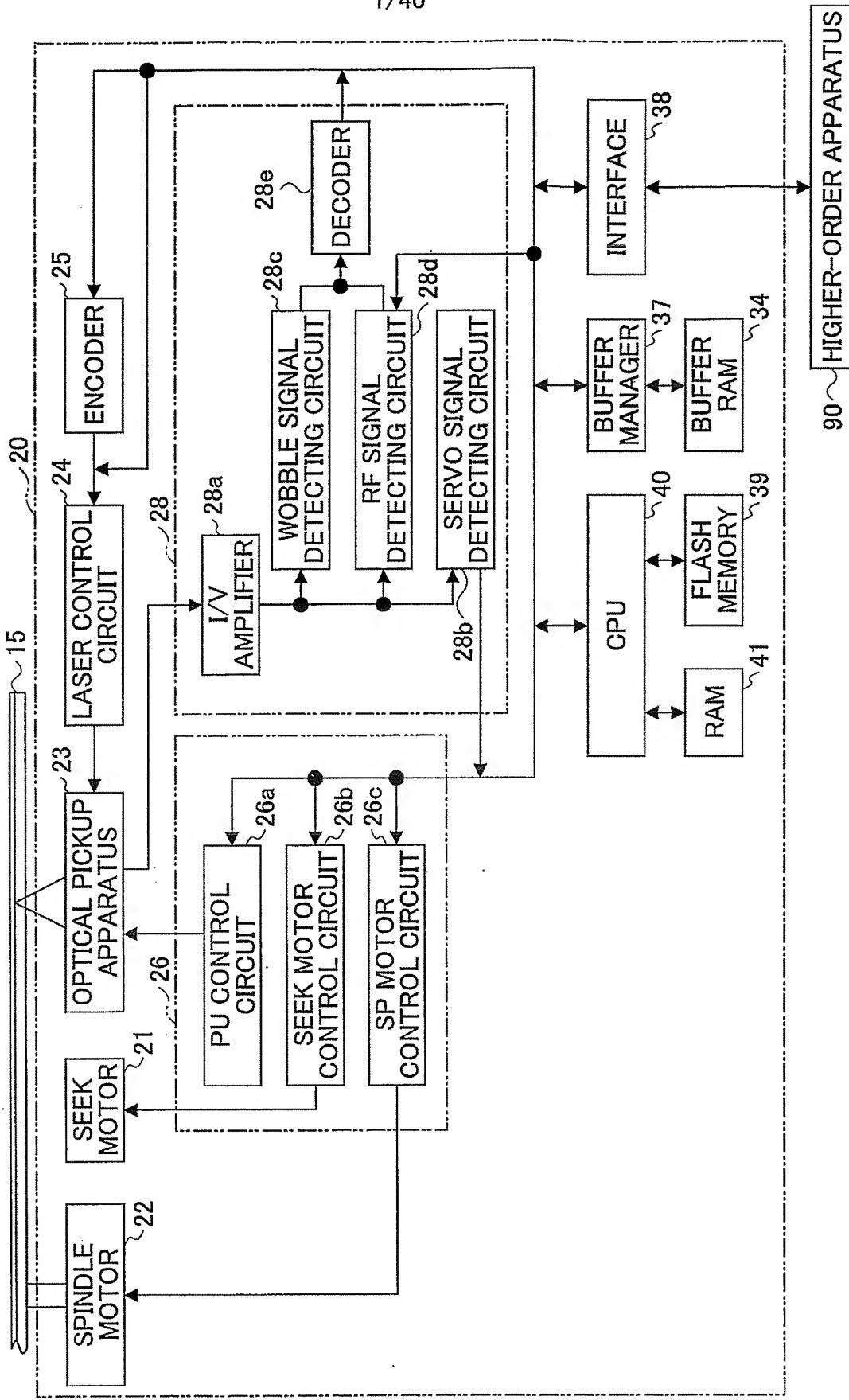
turn the returning light beam into a condensing light beam; and

a light beam regulating unit to extract from the condensing light beam a partial
5 light beam corresponding to part of a cross section of the condensing light beam not exceeding half of the cross section as divided by a straight line passing through a center of the cross section; and

one or more photo detectors, situated
10 between a position where the light reflected by the first recording layer contained in the partial light beam is condensed and a position where the light reflected by the second recording layer contained in the partial light beam is condensed, said one or
15 more photo detectors having a first photo detecting section to detect the light reflected by the first recording layer and a second photo detecting section to detect the light reflected by the second recording layer.

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FIG. 1



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FIG.2

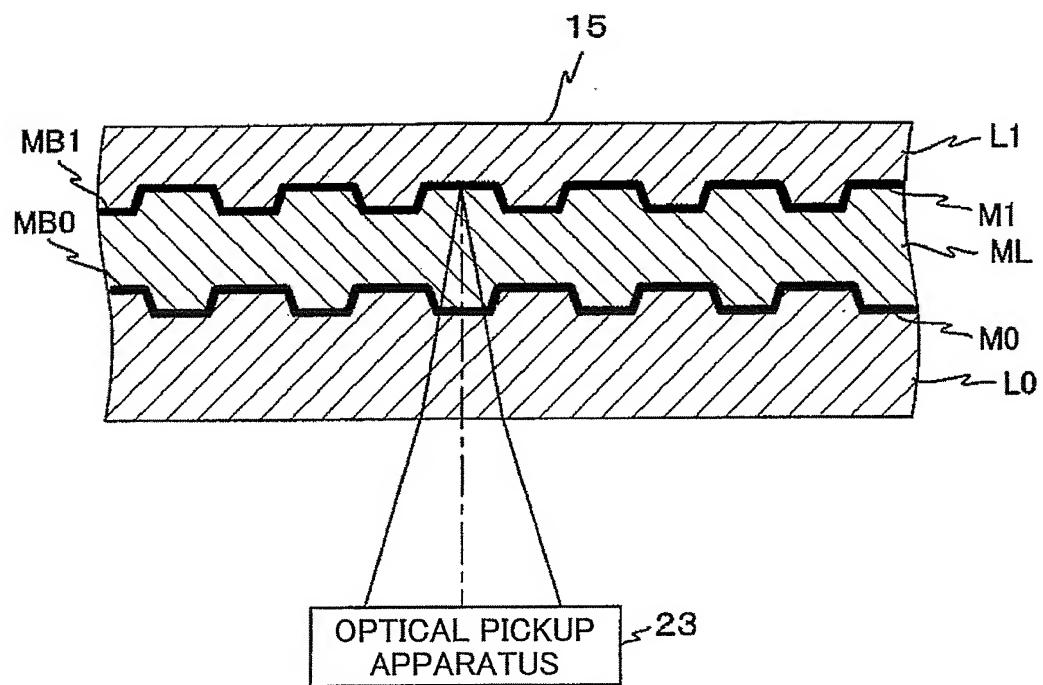


FIG.3A

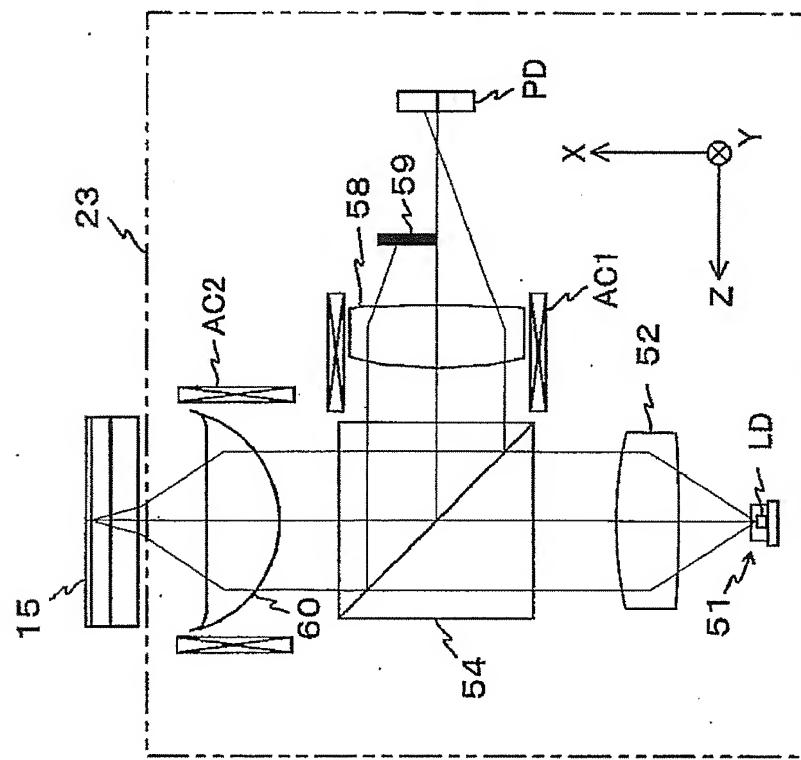


FIG.3B

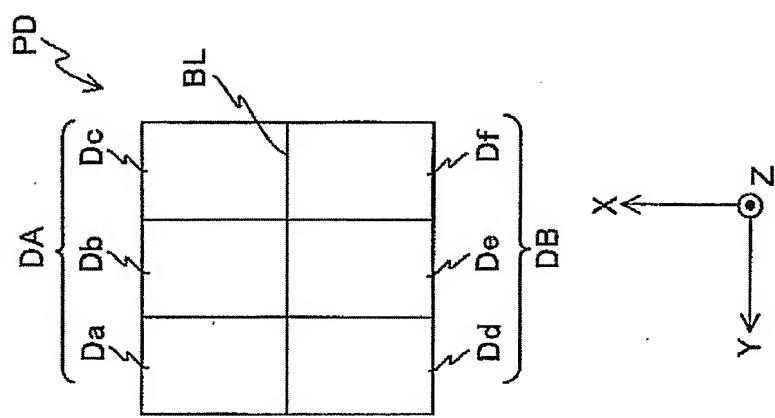
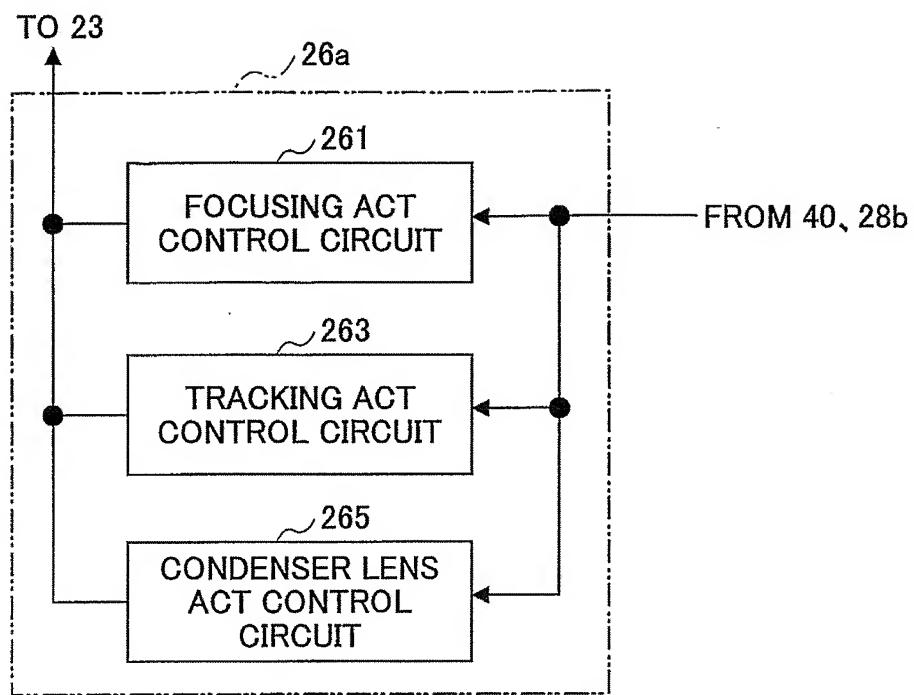


FIG.4



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FIG.5A

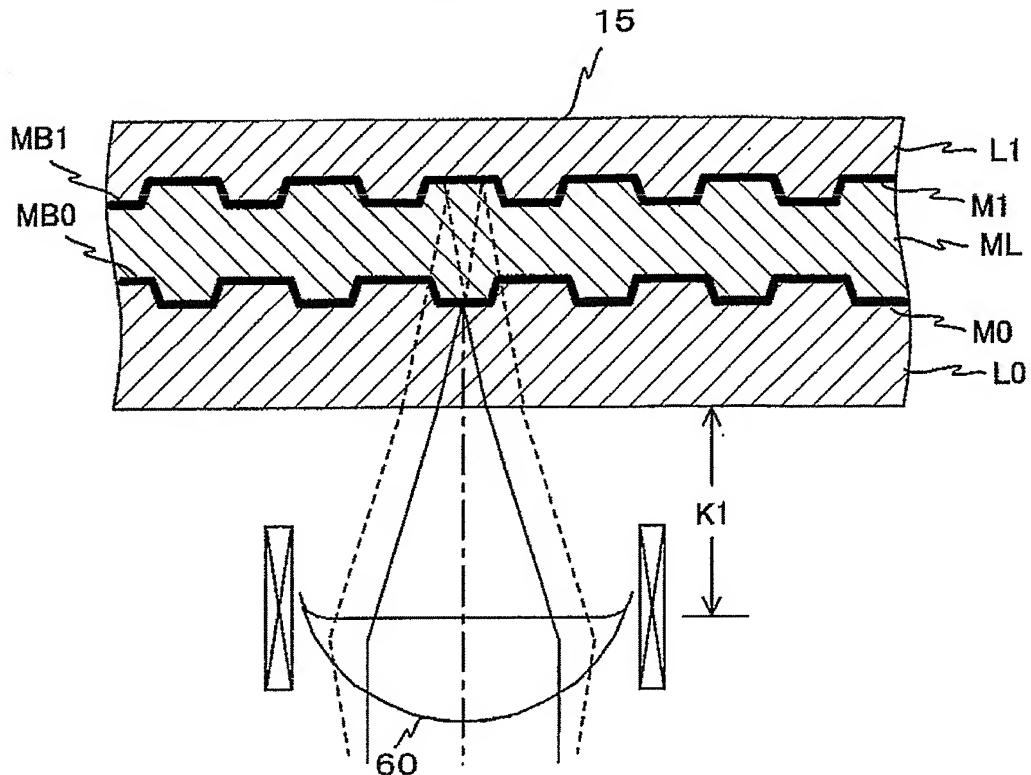
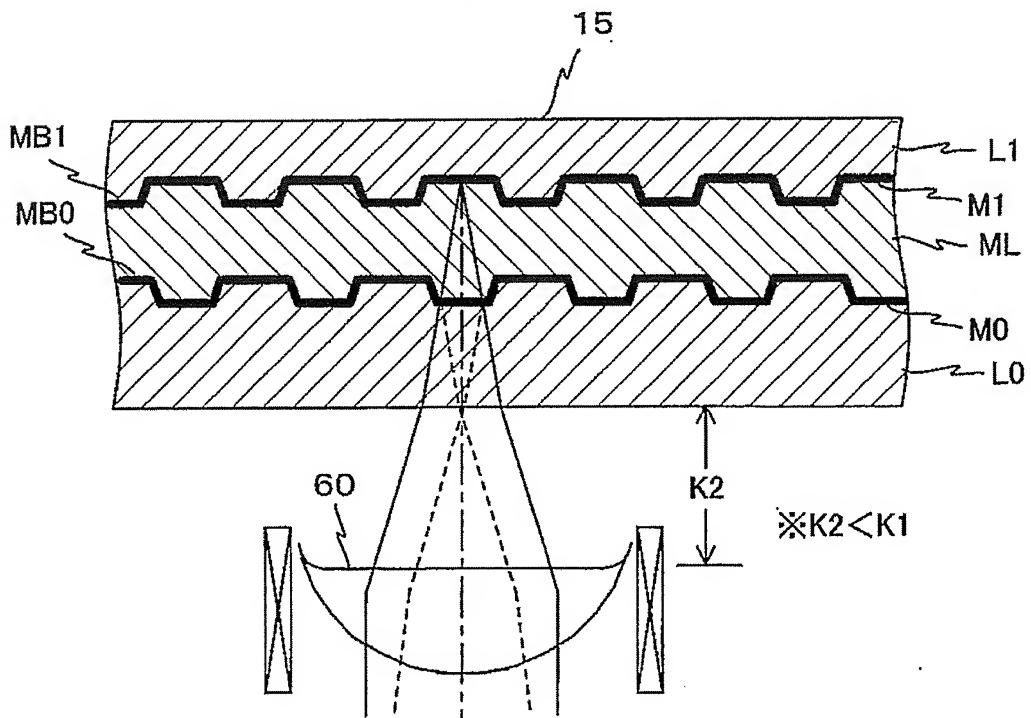


FIG.5B



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FIG.6A

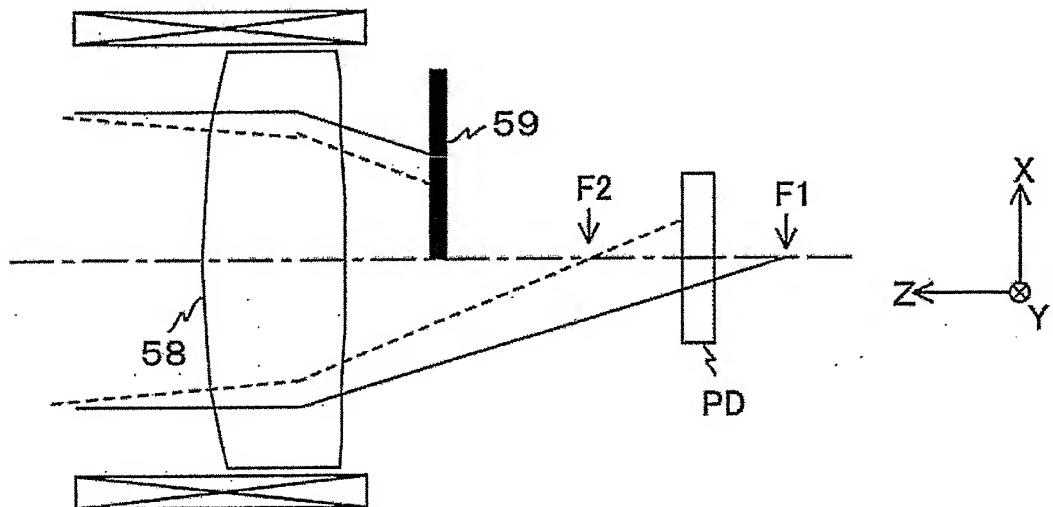


FIG.6B

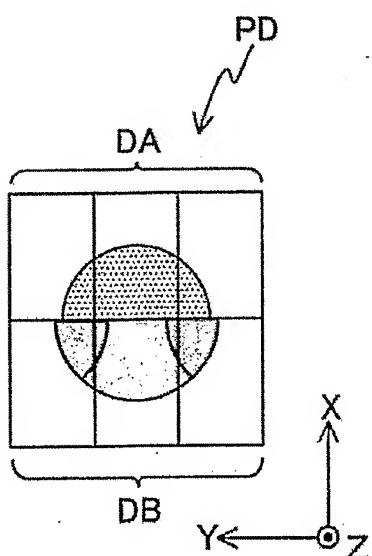
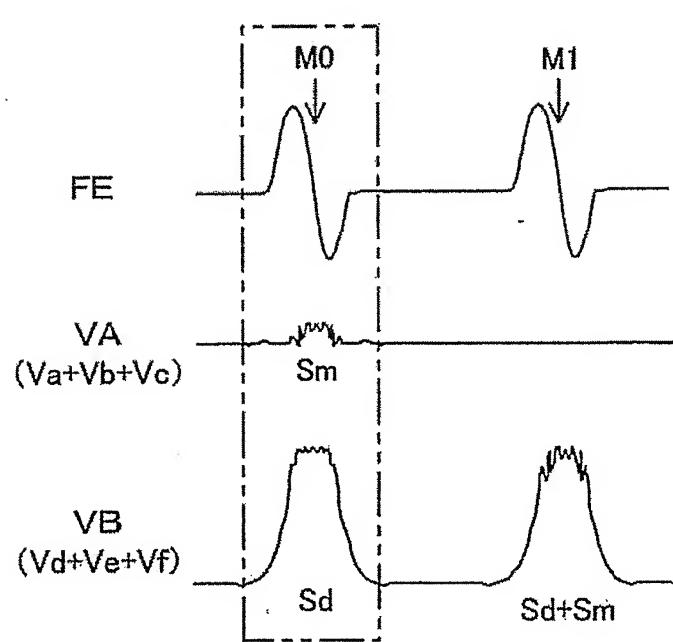


FIG.6C



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FIG.7A

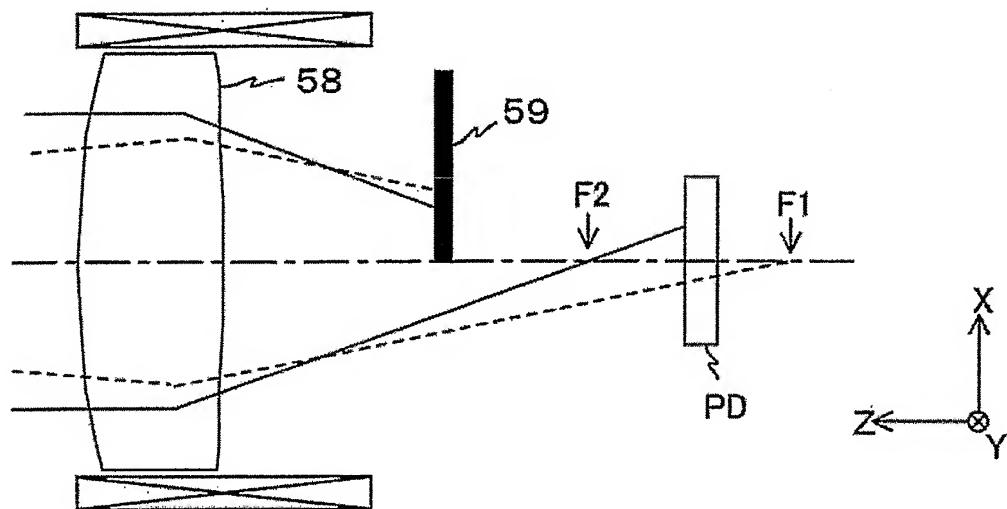


FIG.7B

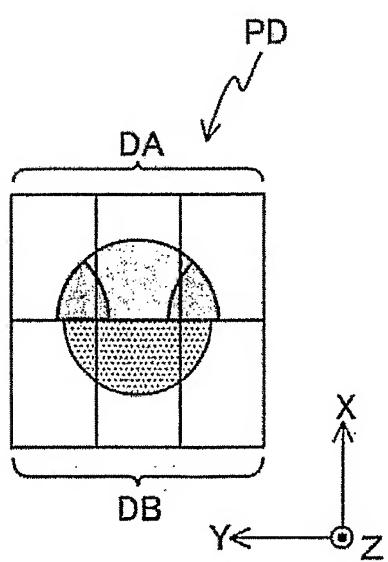


FIG.7C

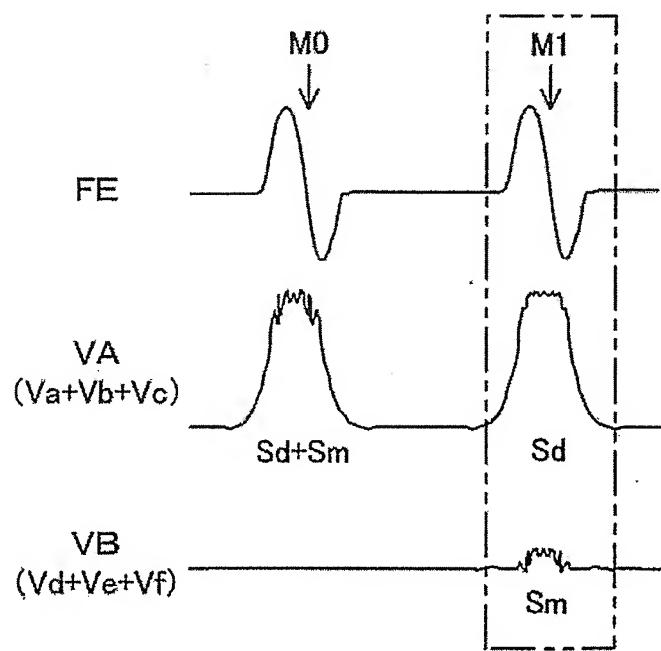
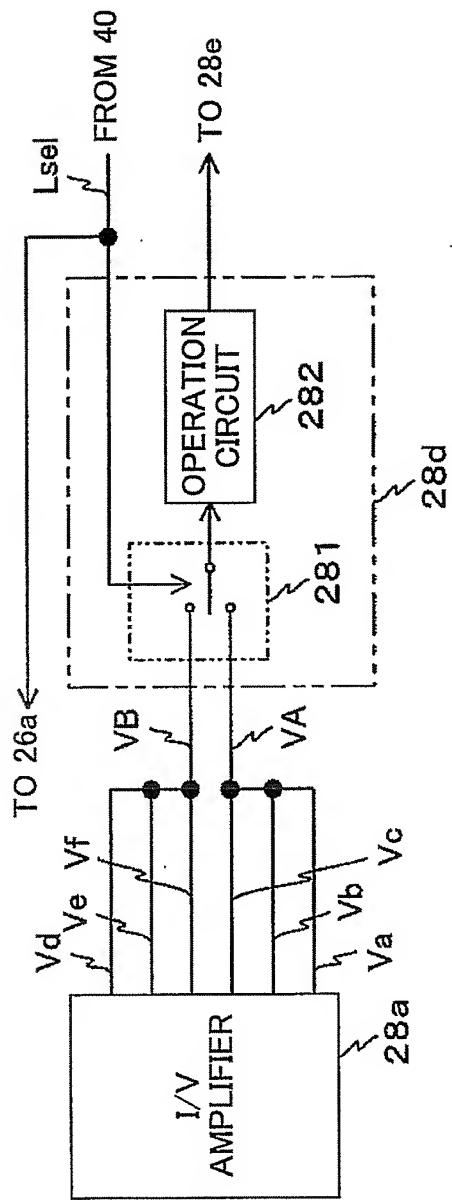


FIG.8



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FIG.9A

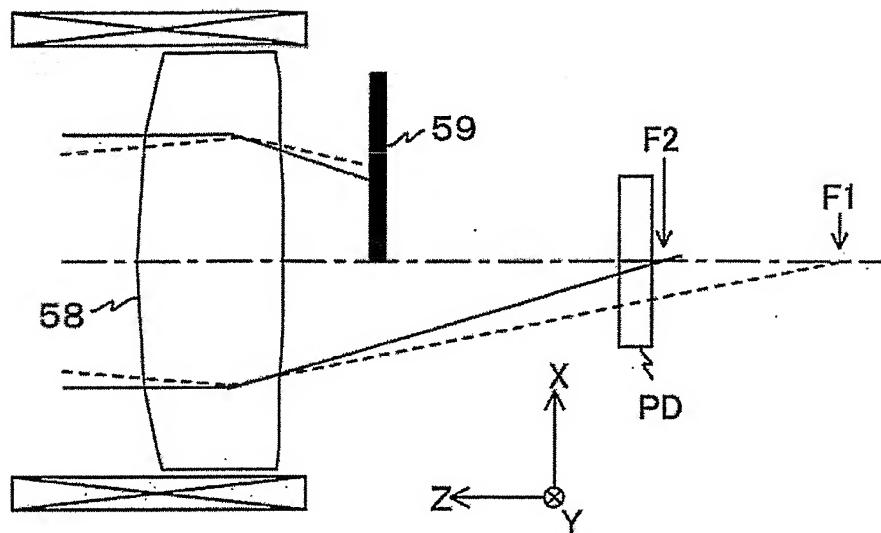


FIG.9B

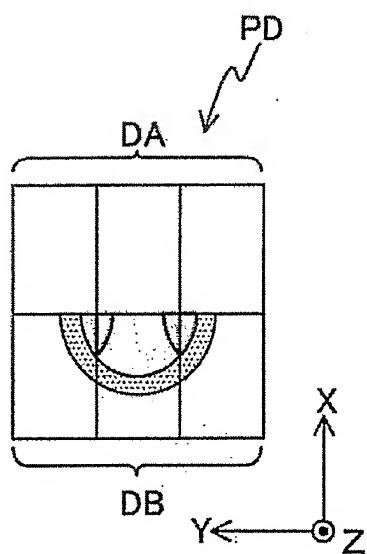
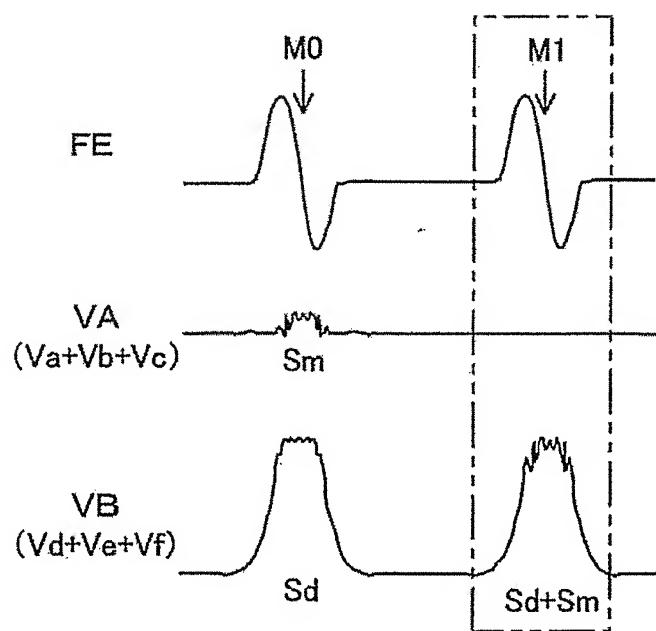


FIG.9C



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FIG.10

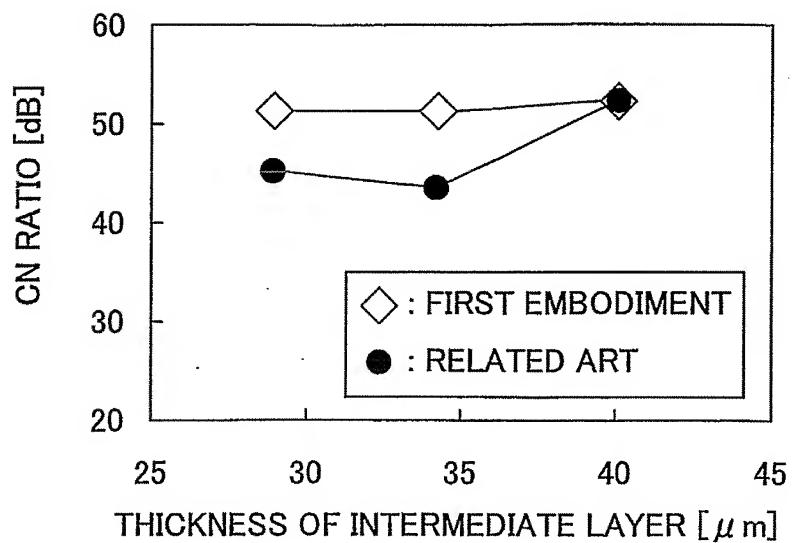
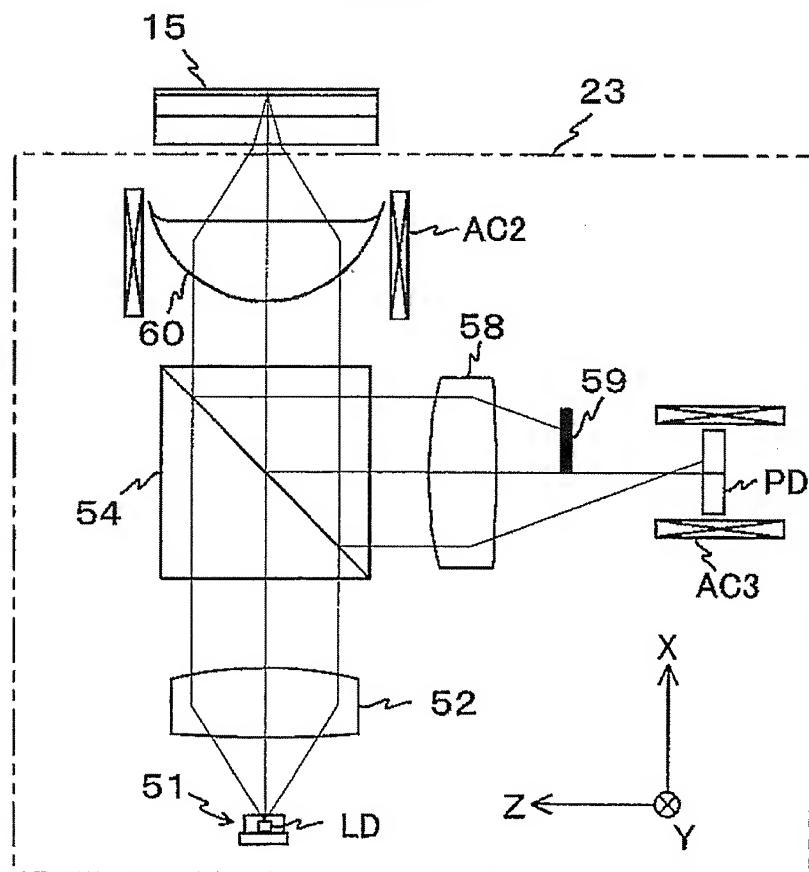
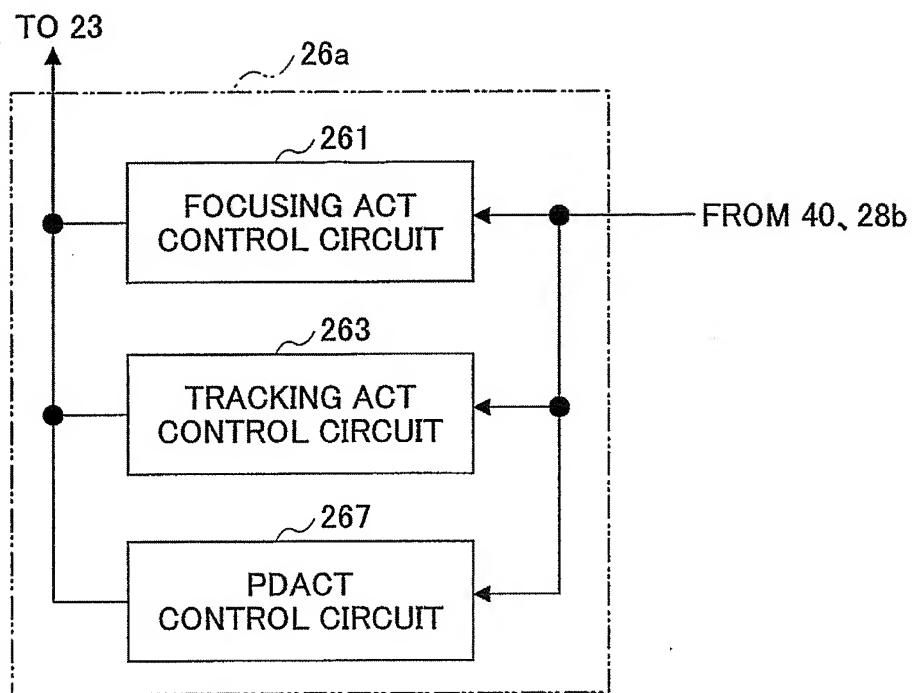


FIG.11



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FIG.12



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FIG.13A

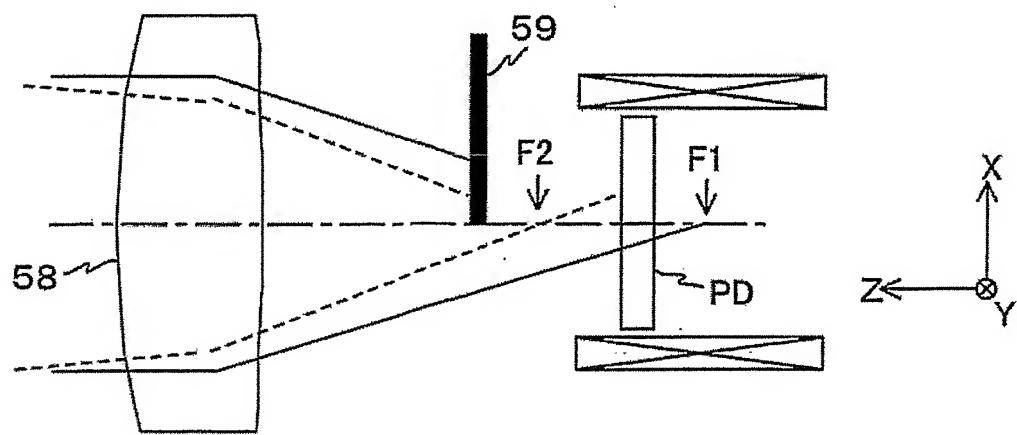


FIG.13B

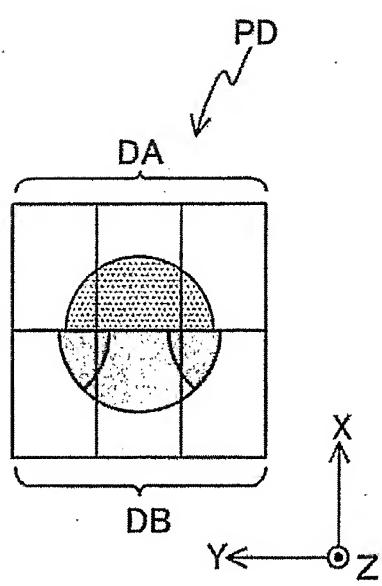
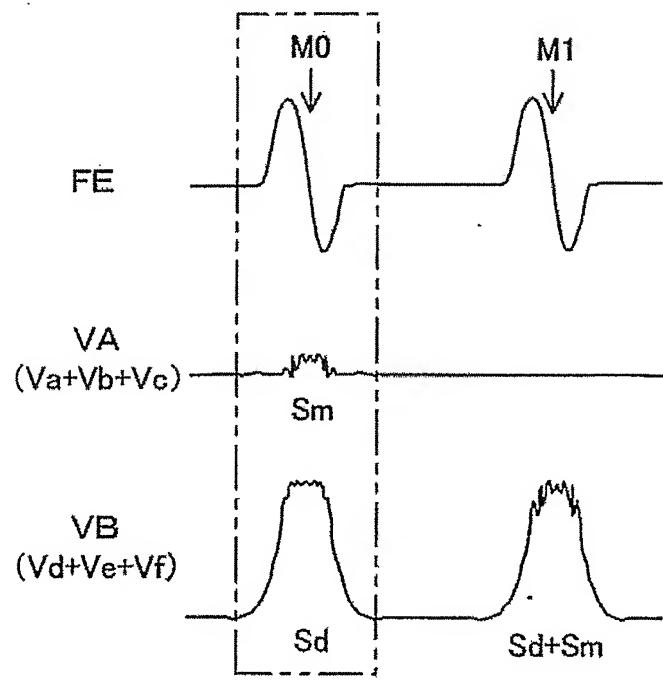


FIG.13C



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FIG.14A

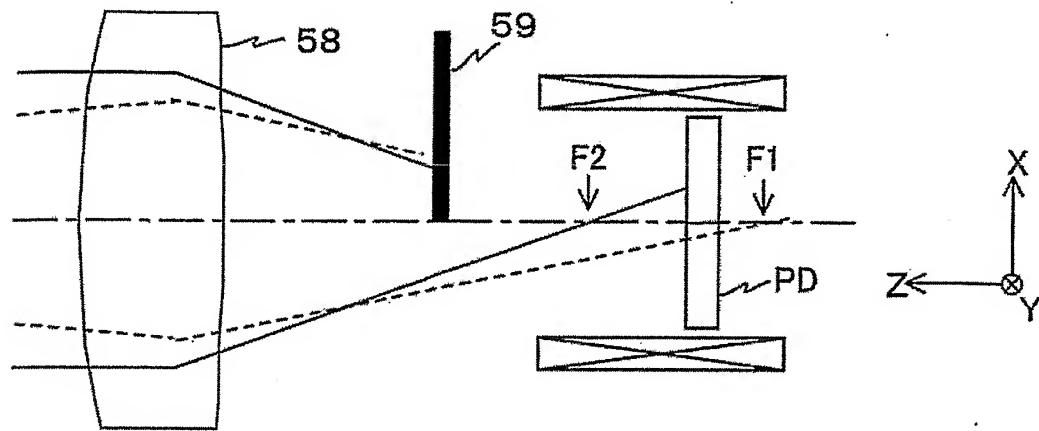


FIG.14B

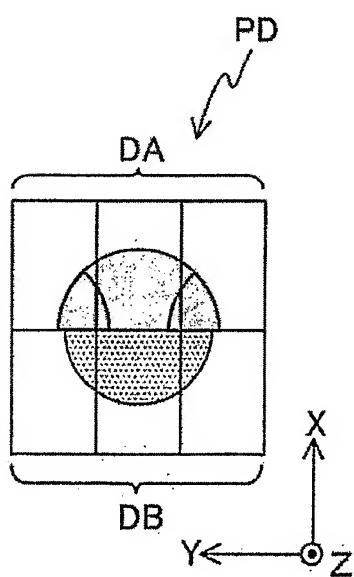
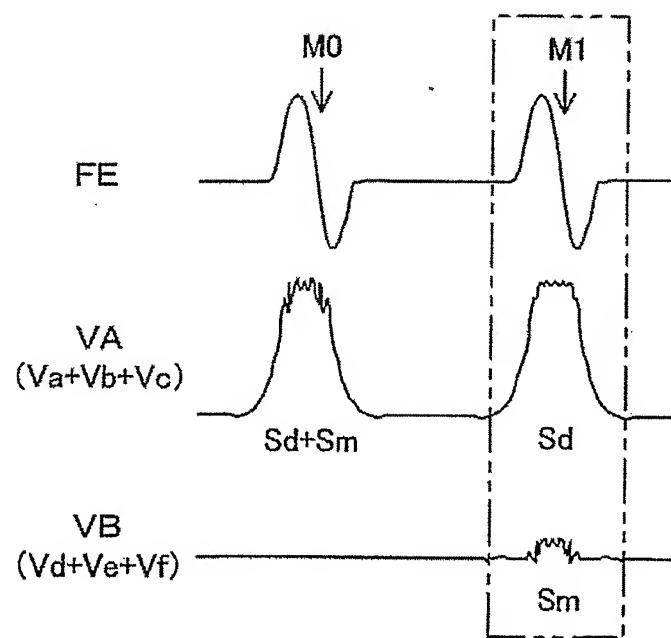
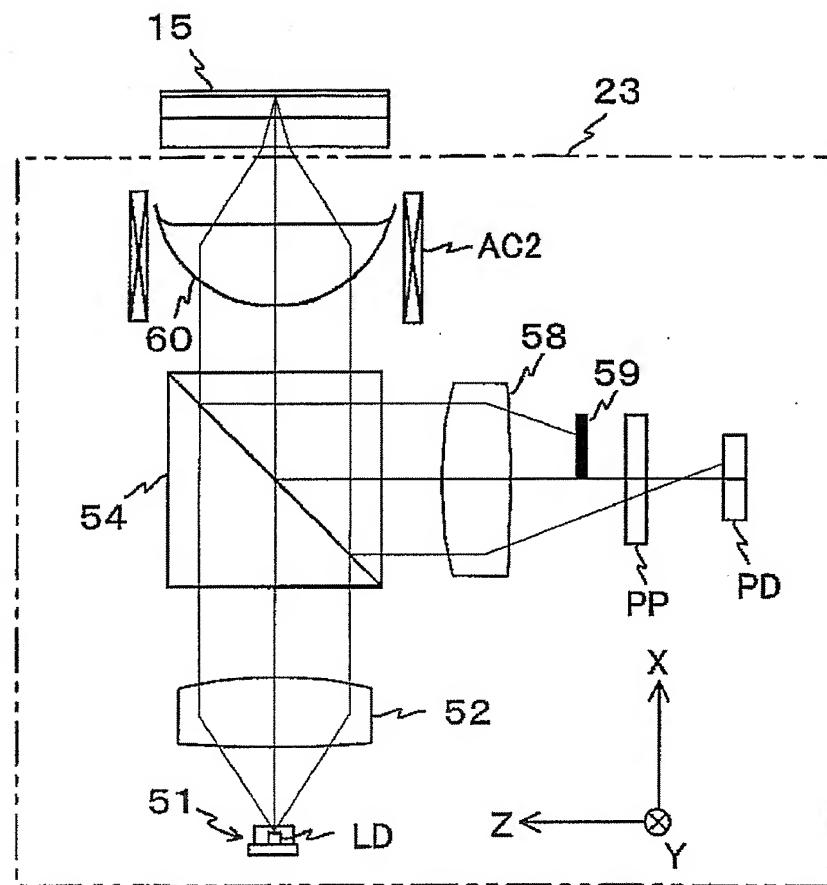


FIG.14C



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FIG.15



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FIG.16

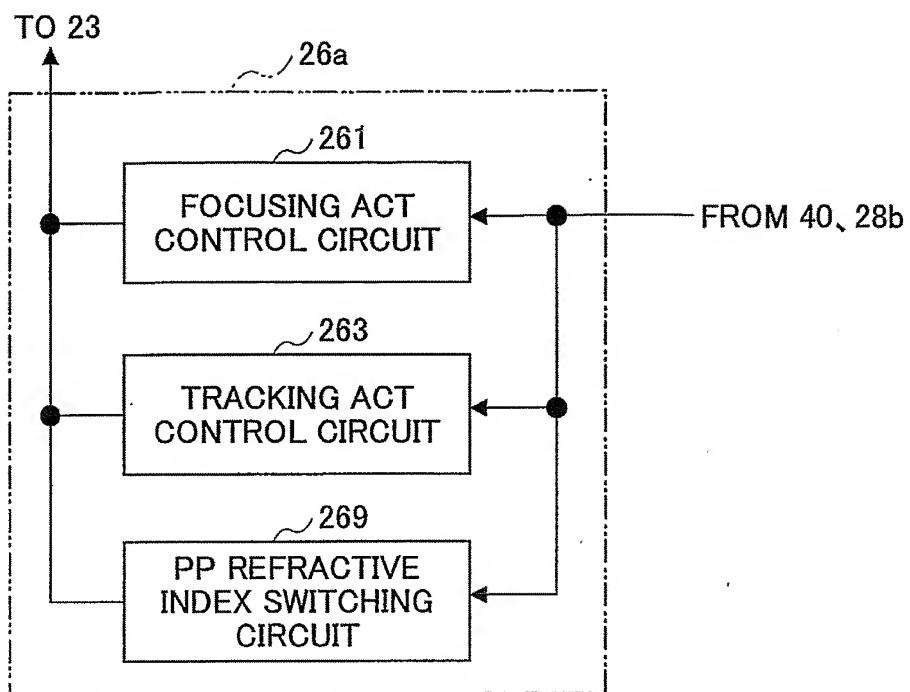


FIG.17B

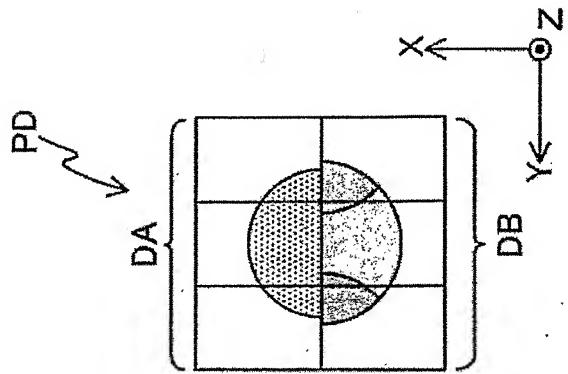


FIG.17A

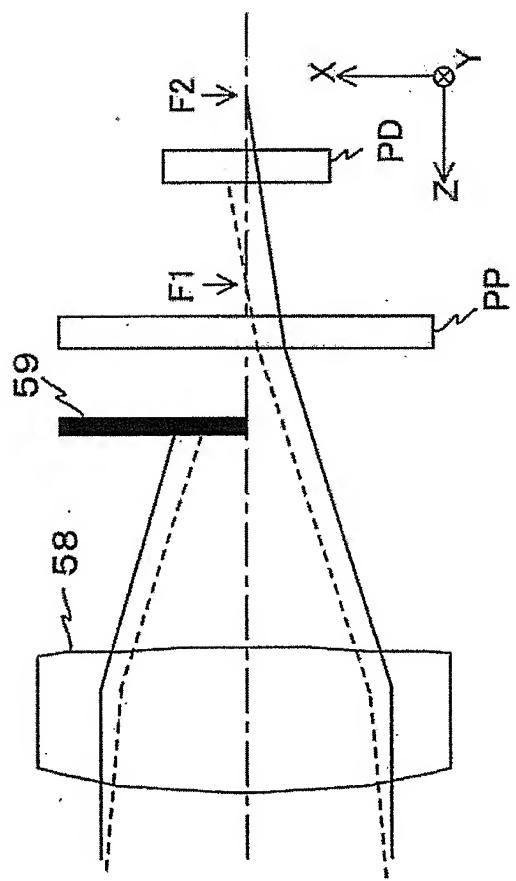


FIG.18B

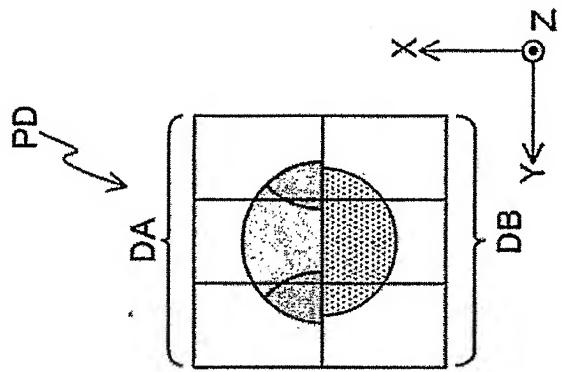
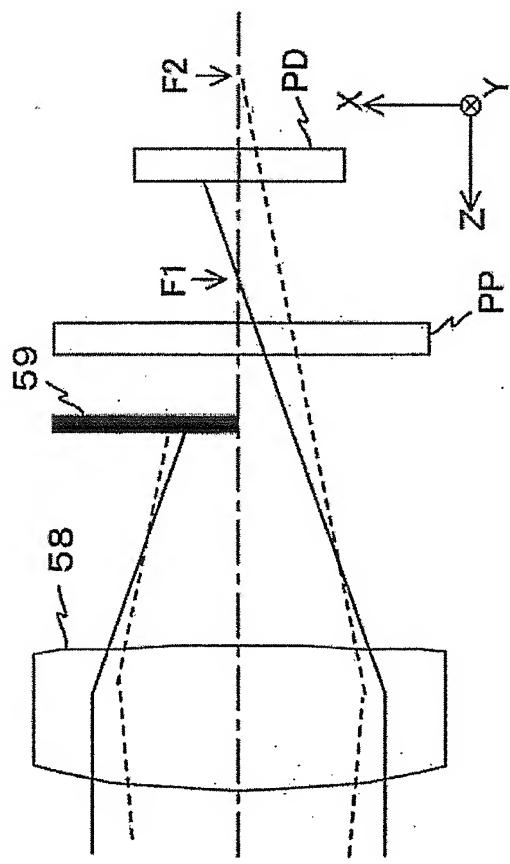


FIG.18A



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FIG.19A

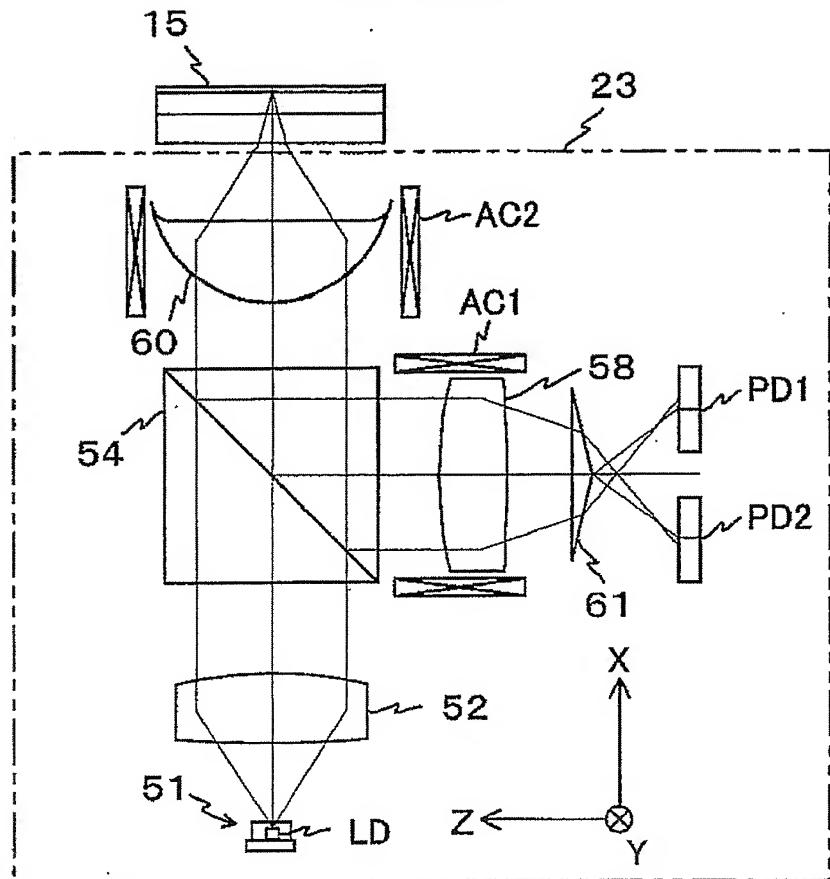
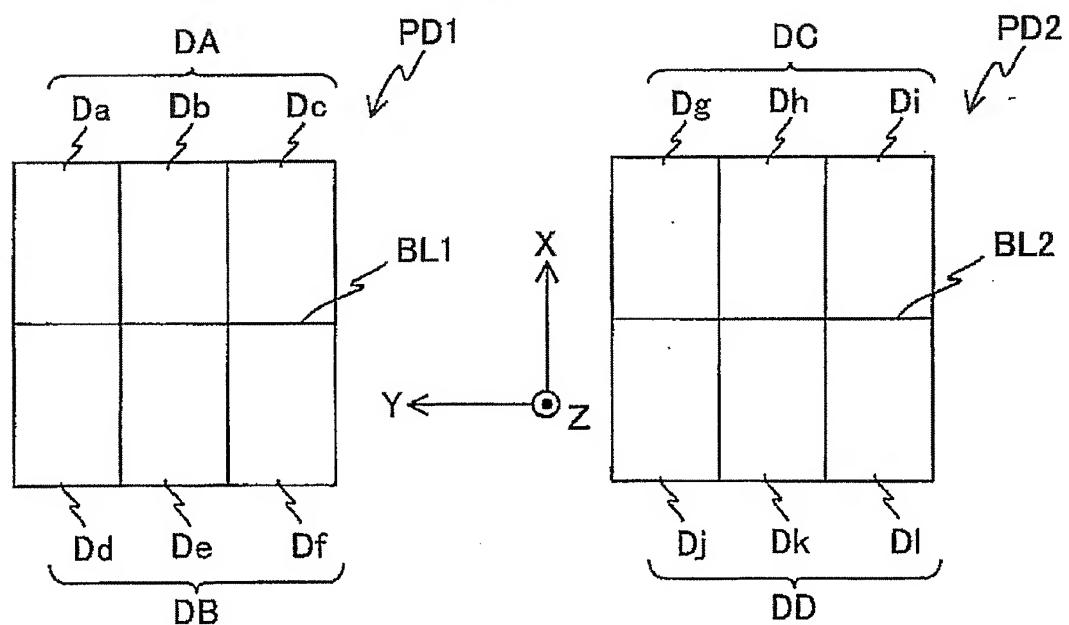


FIG.19B



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FIG.20A

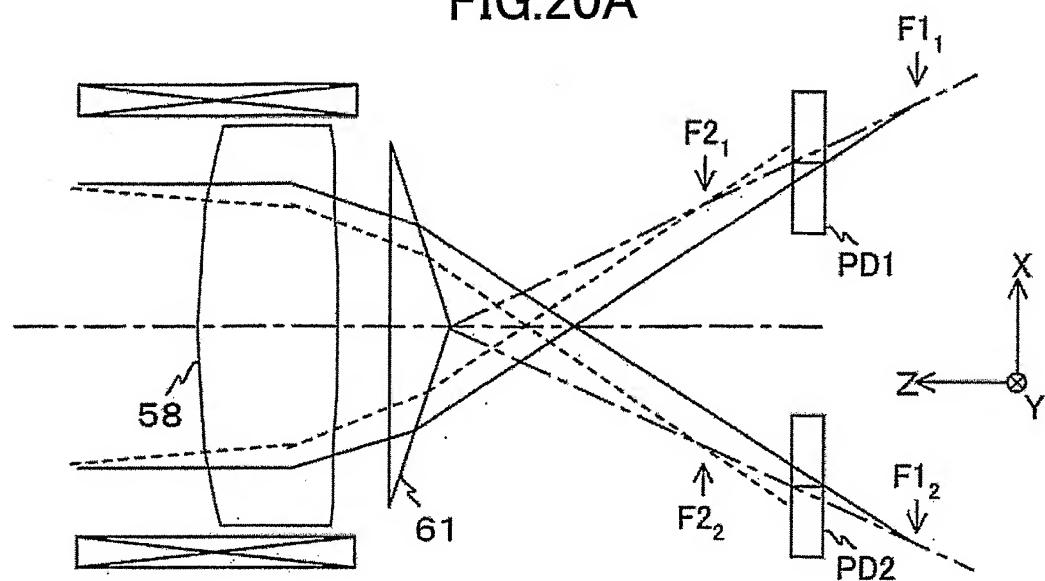


FIG.20B

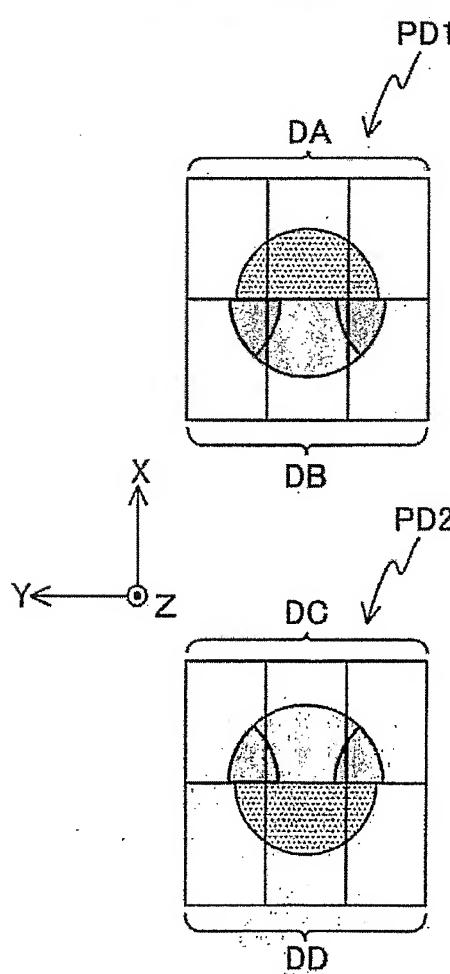
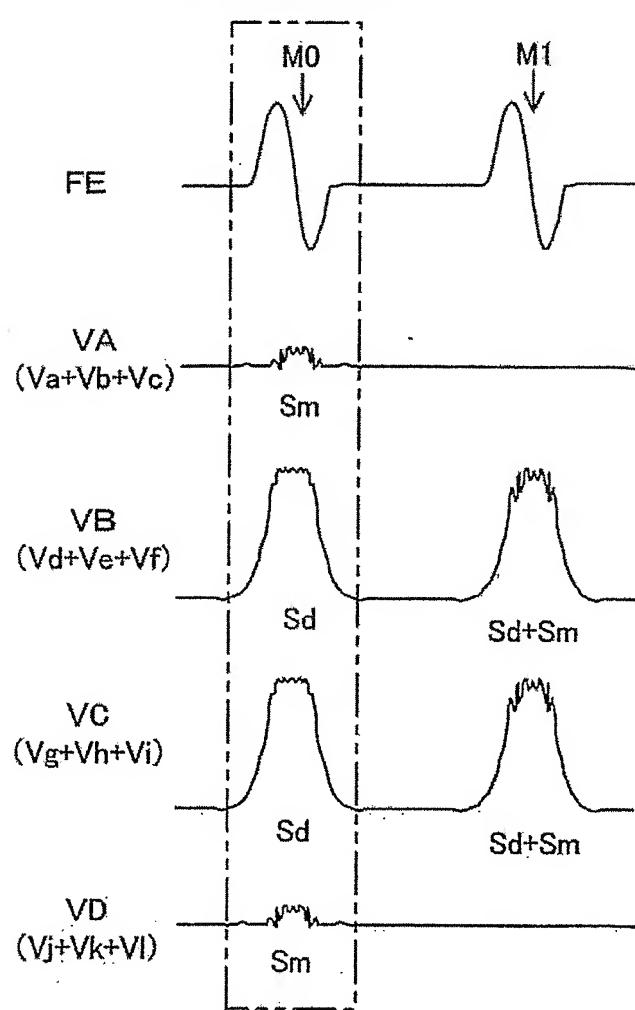


FIG.20C



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FIG.21A

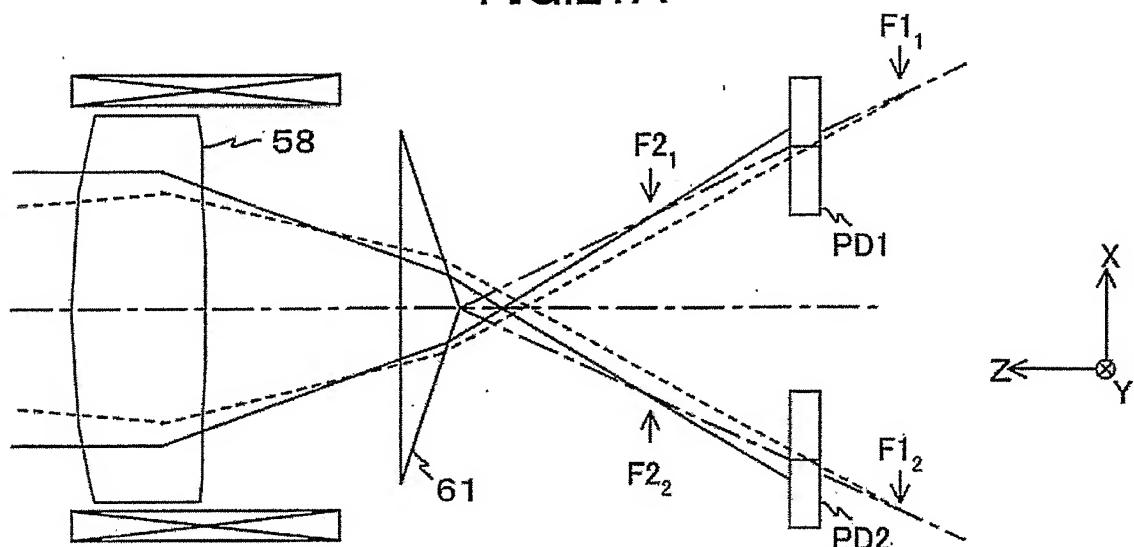


FIG.21B

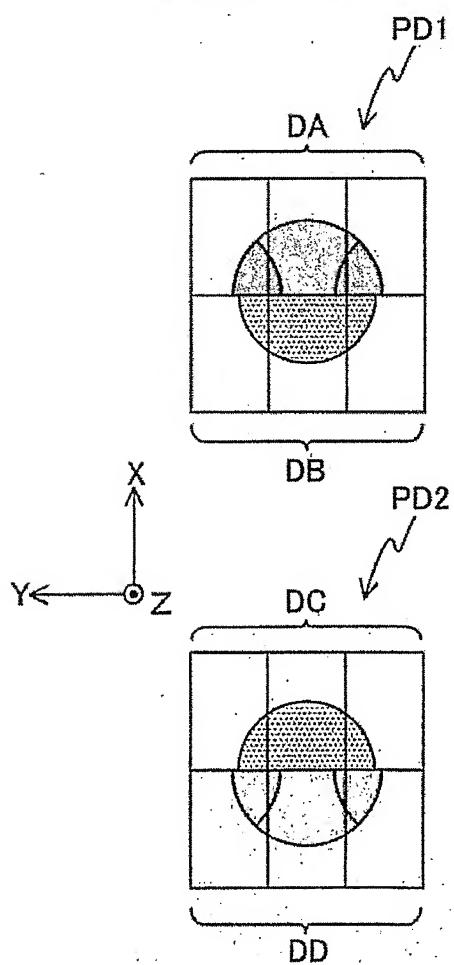


FIG.21C

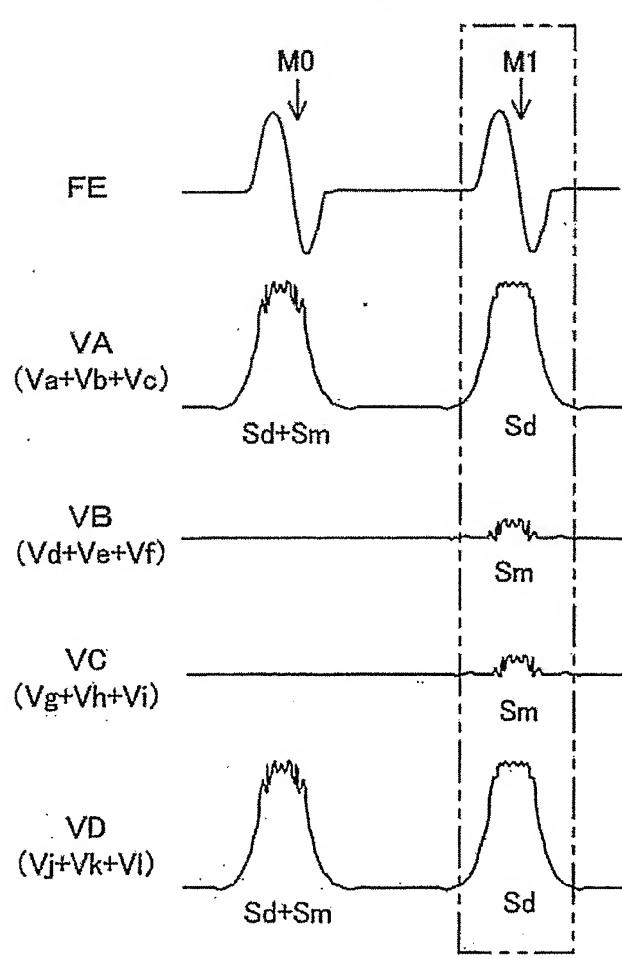
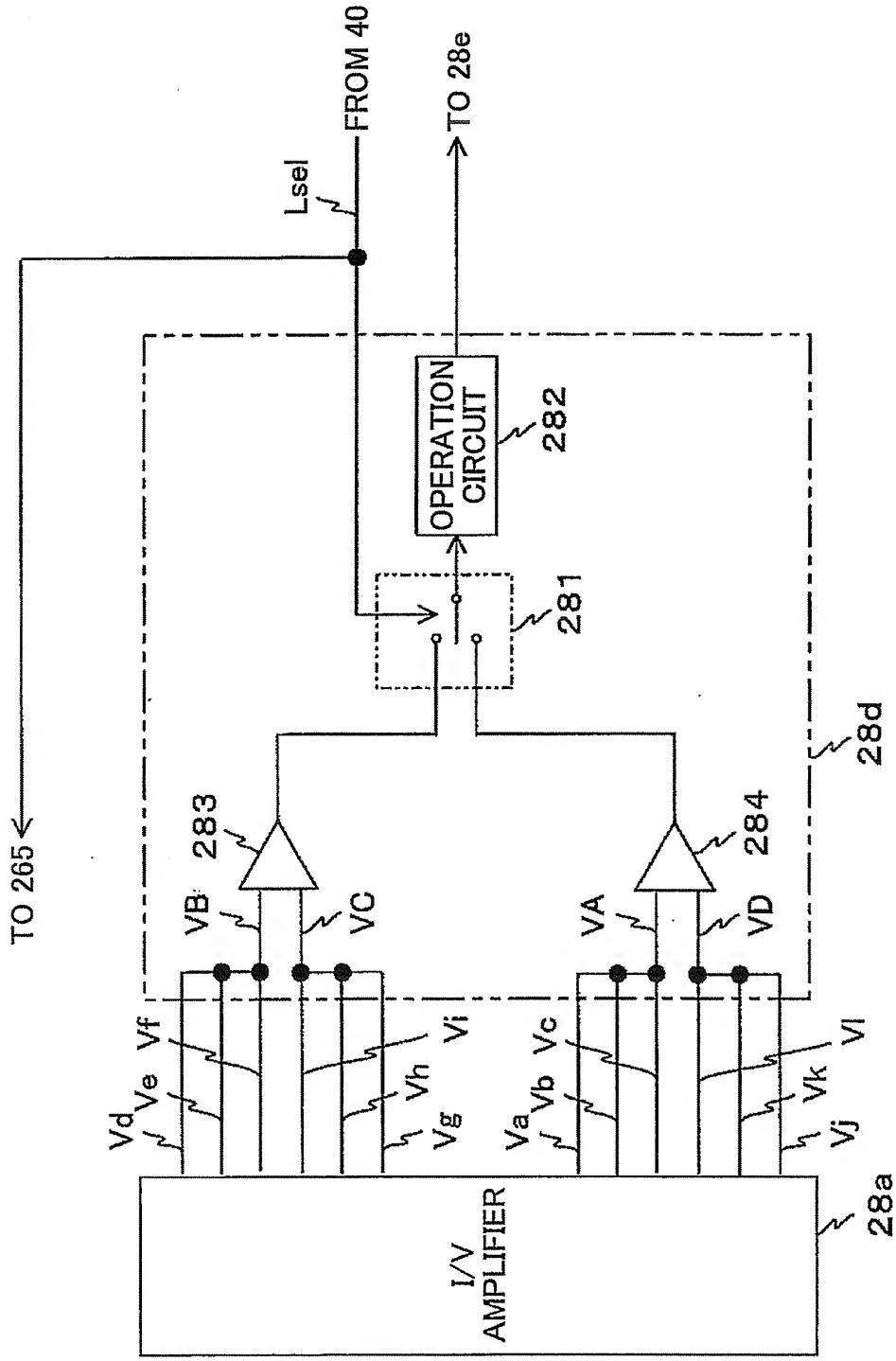


FIG.22



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FIG.23A

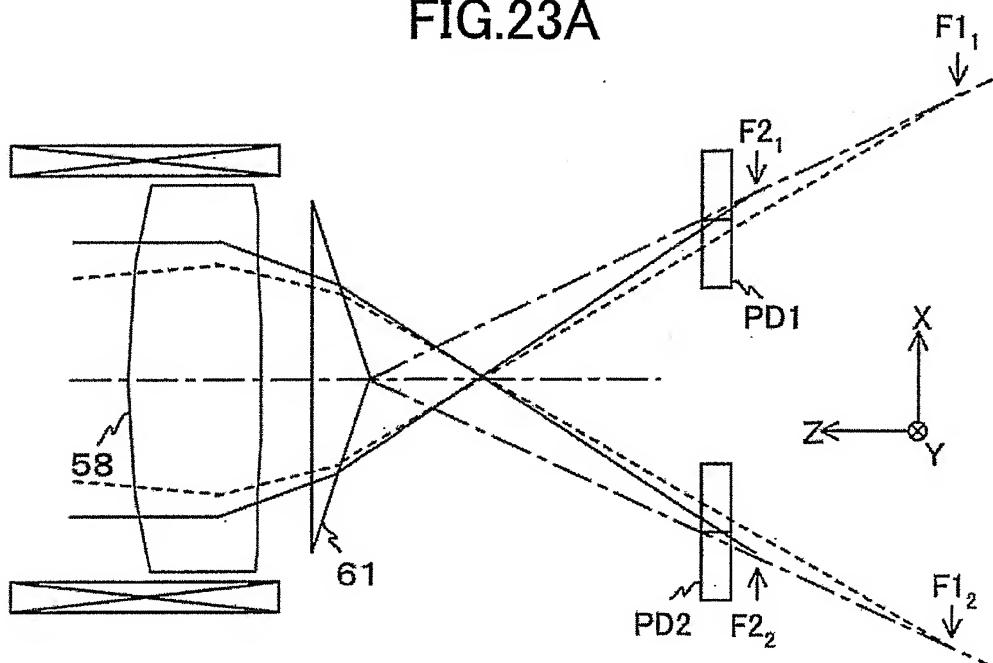


FIG.23B

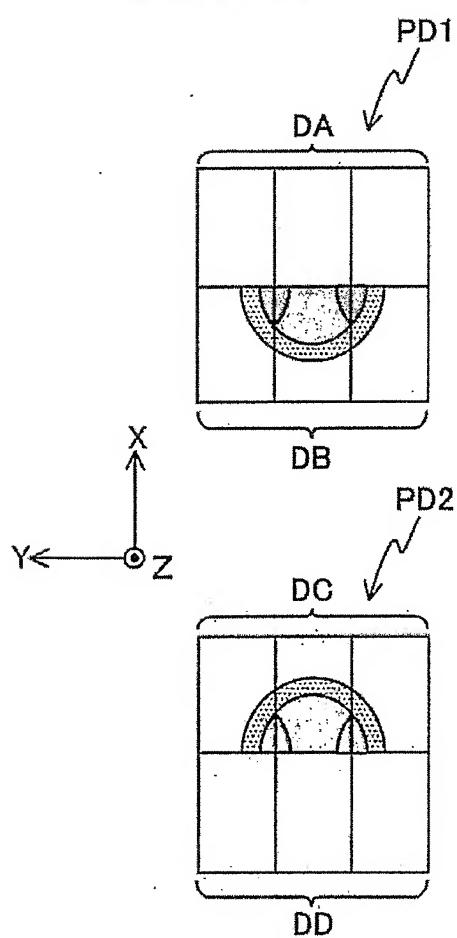
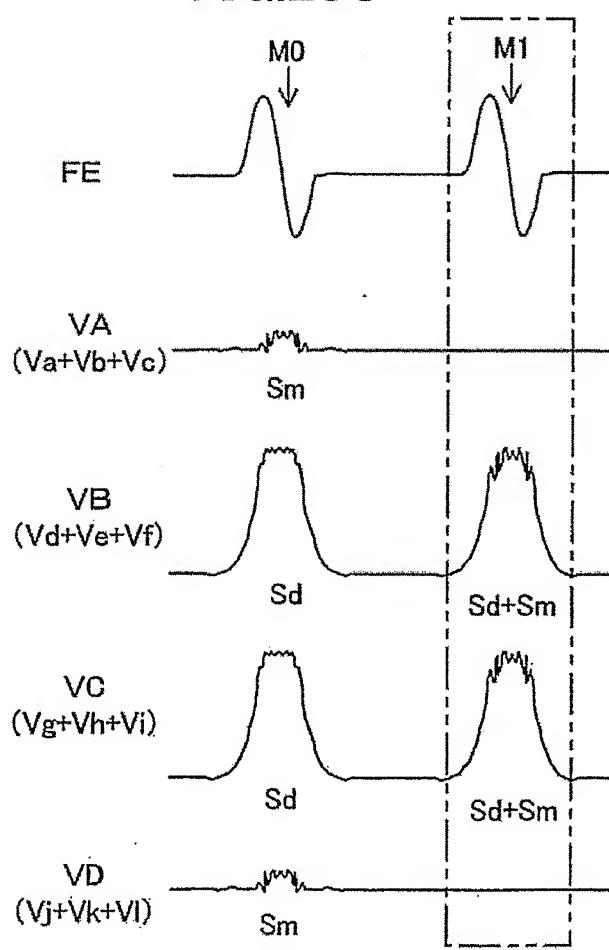
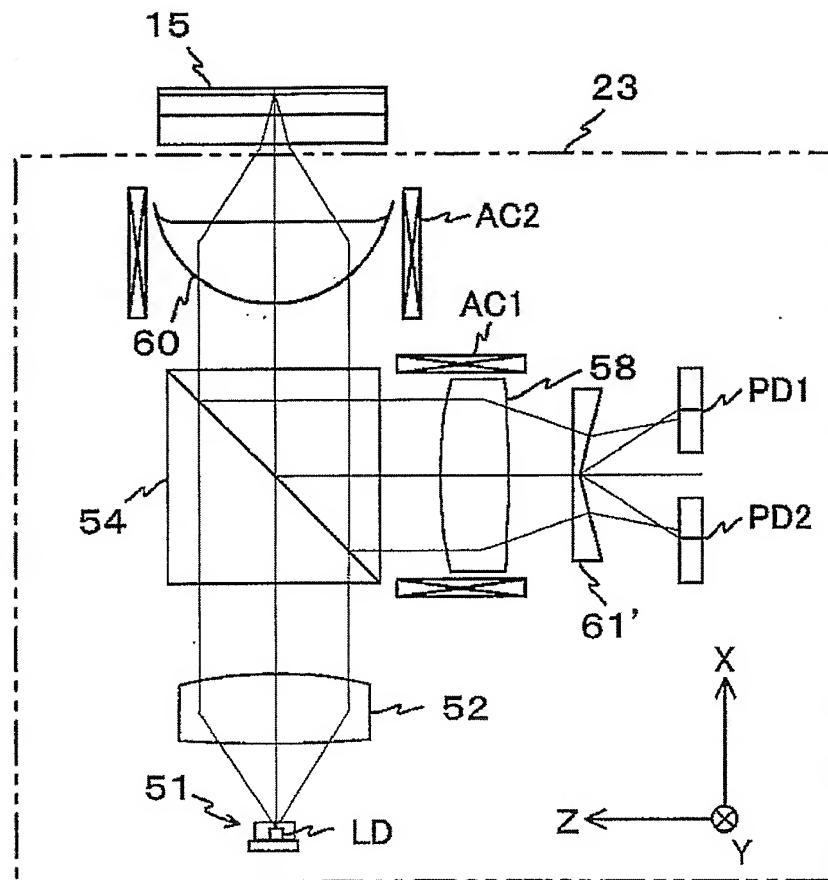


FIG.23C



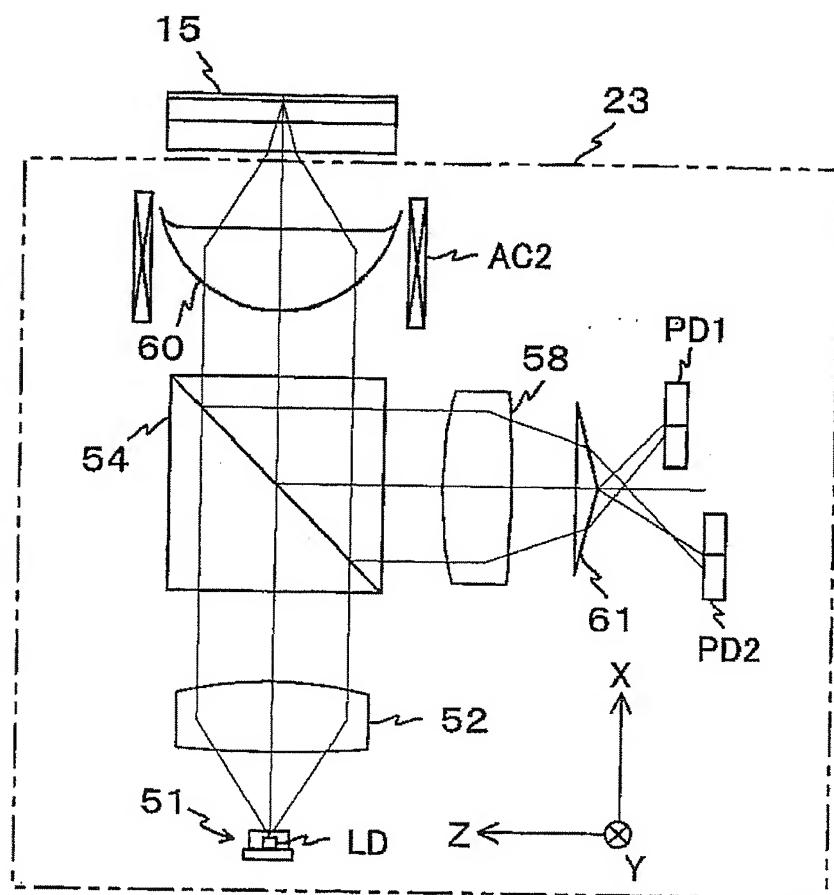
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FIG.24



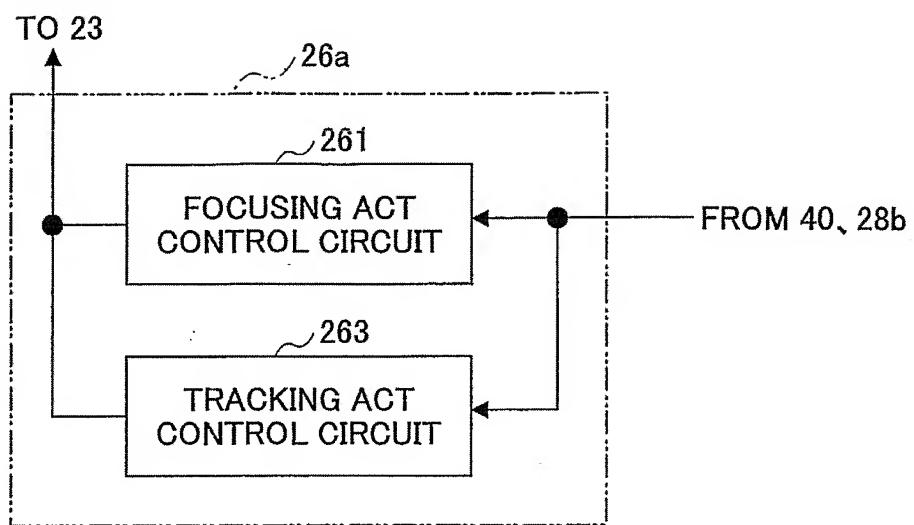
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FIG.25



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FIG.26



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FIG.27A

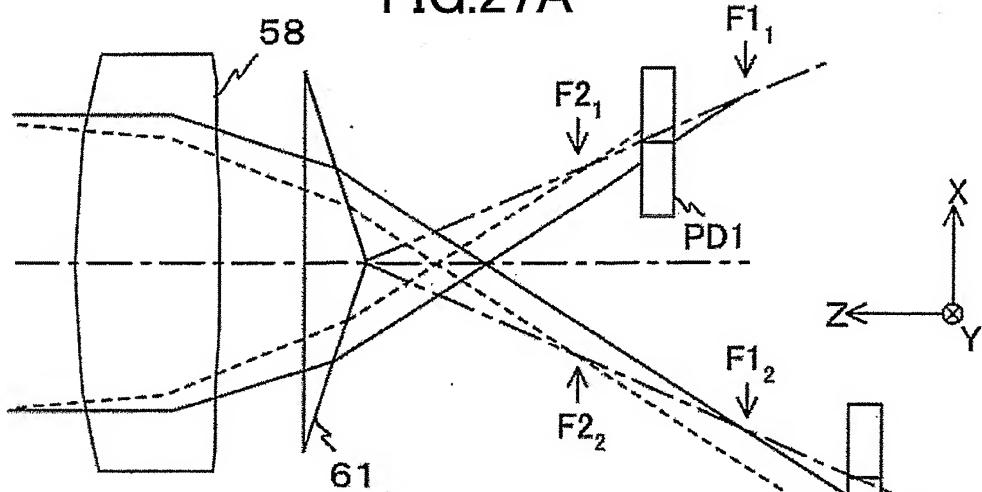


FIG.27B

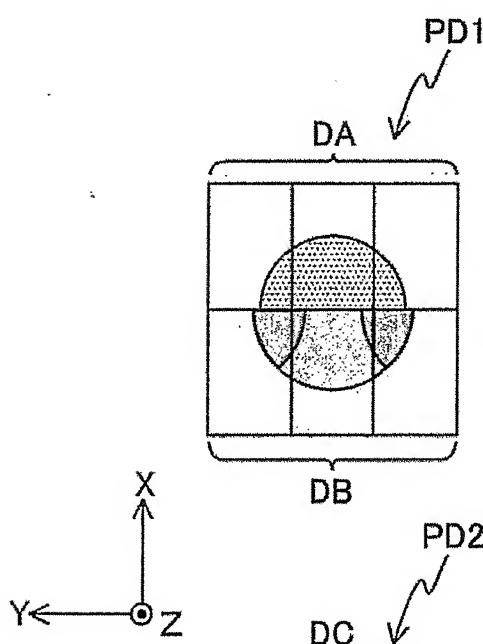
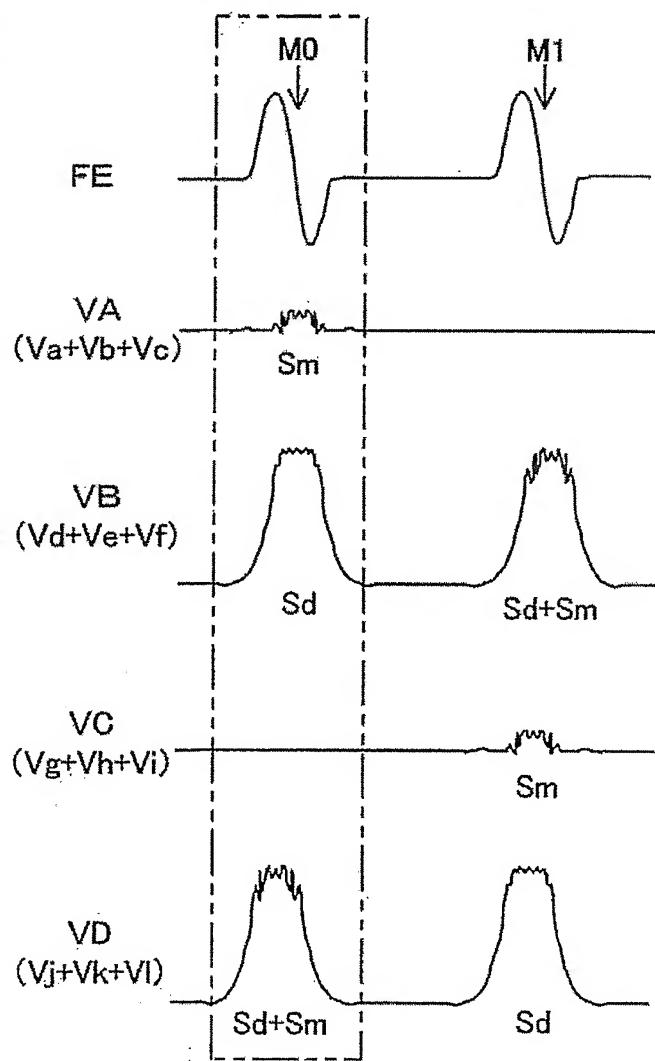


FIG.27C



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FIG.28A

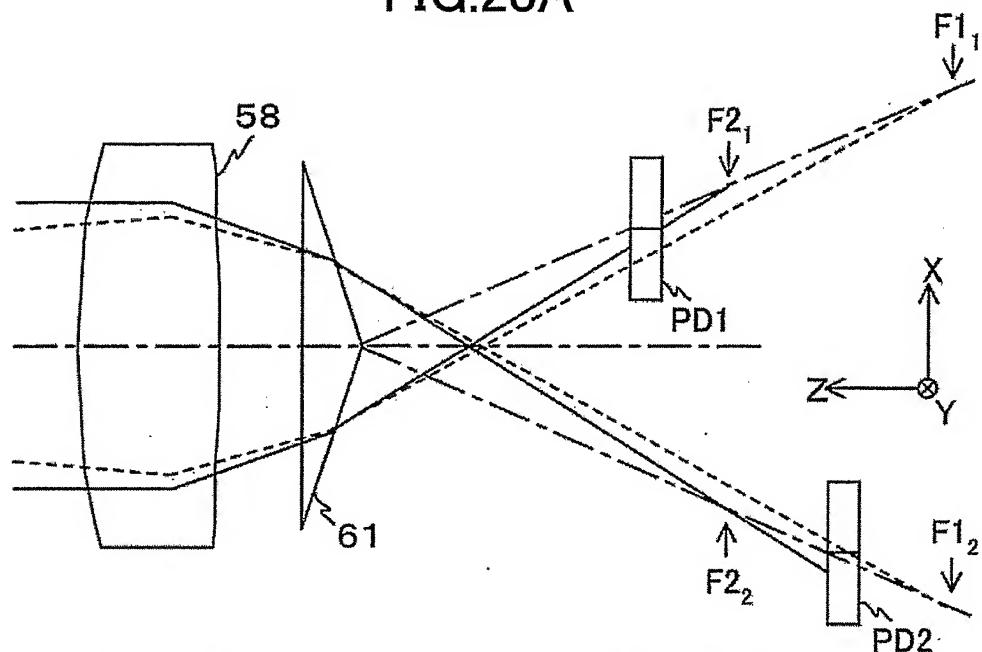


FIG.28B

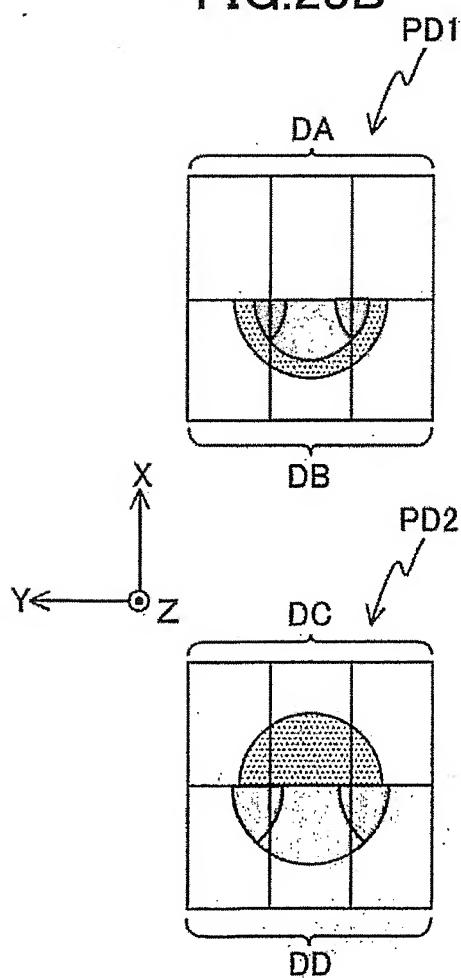


FIG.28C

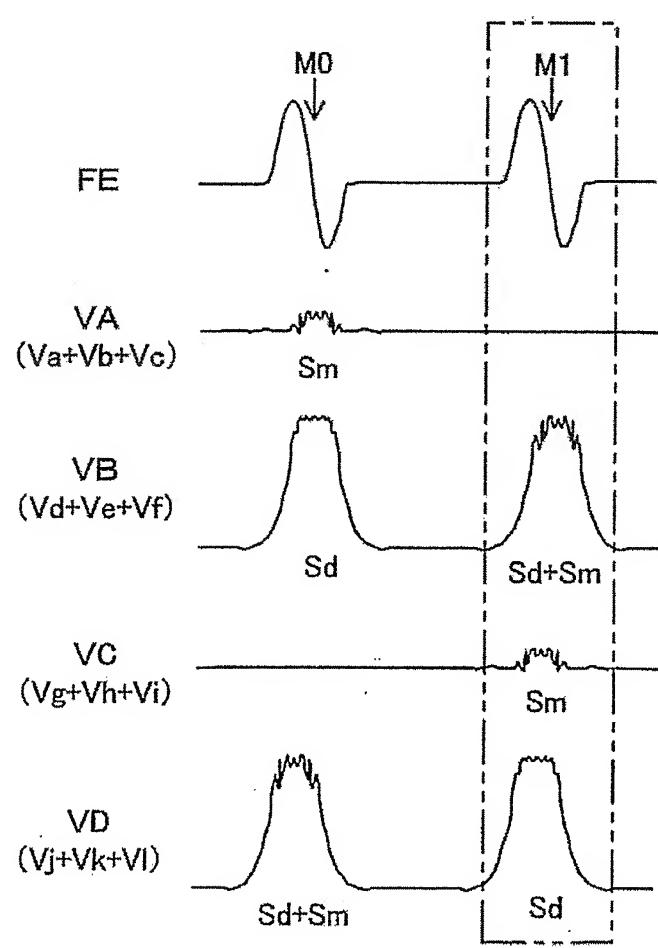


FIG.29

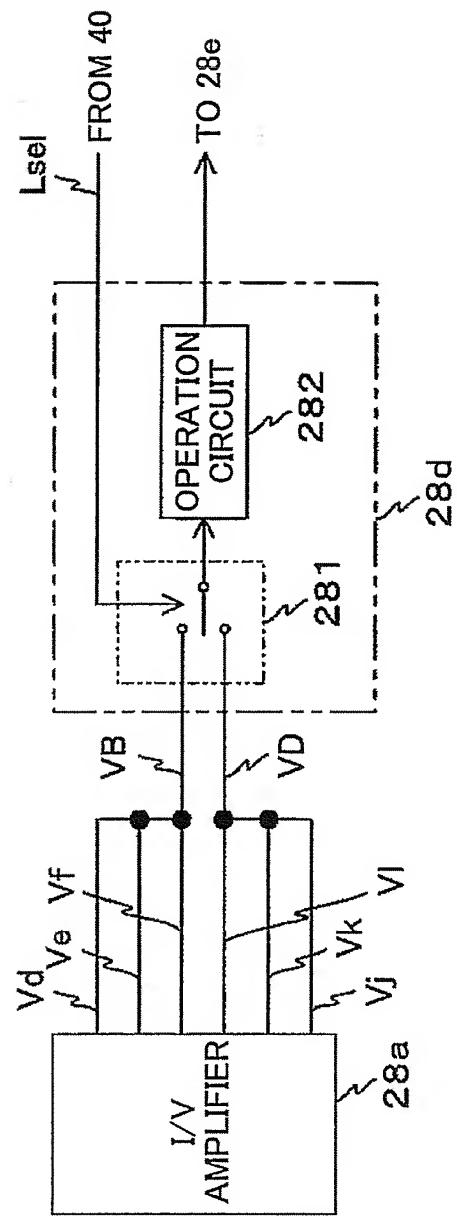
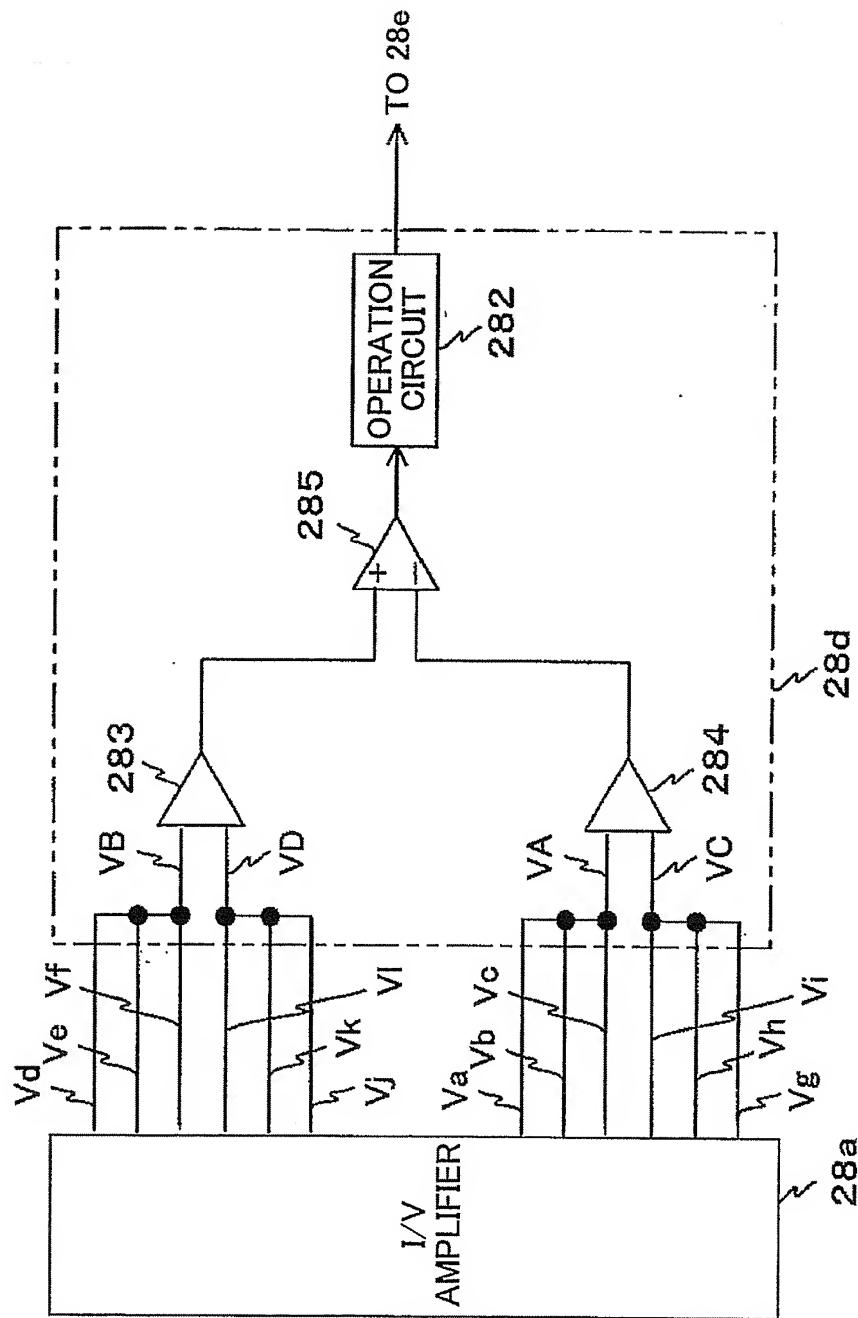


FIG.30



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FIG.31A

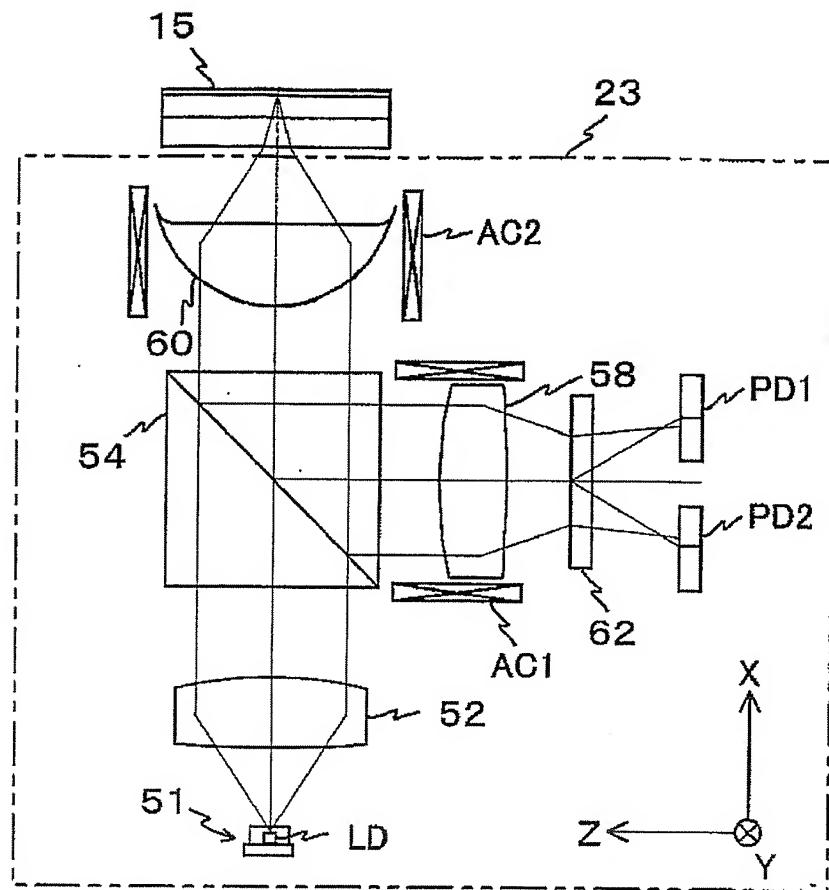
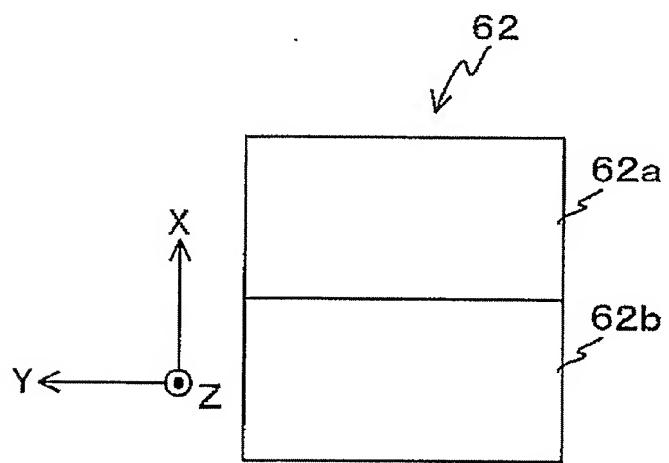


FIG.31B



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FIG.32A

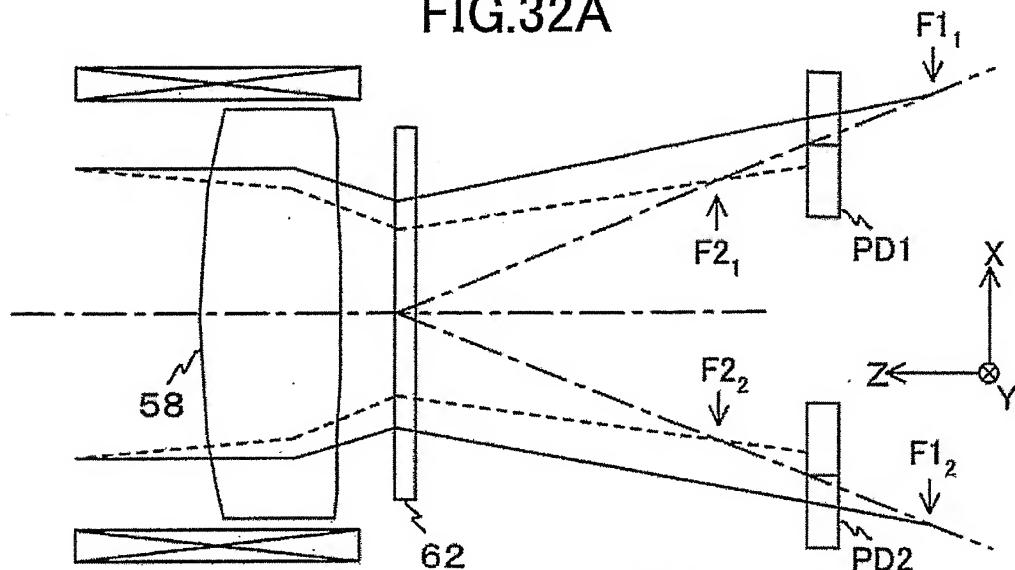


FIG.32B

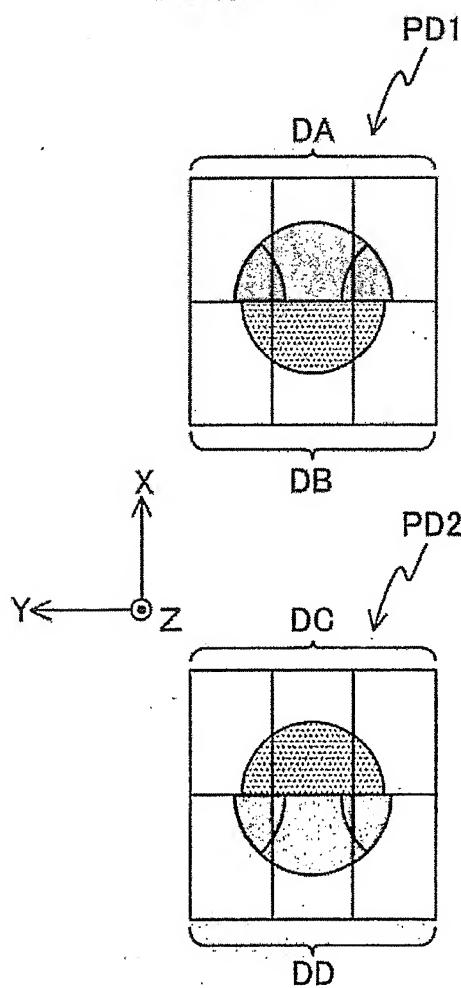
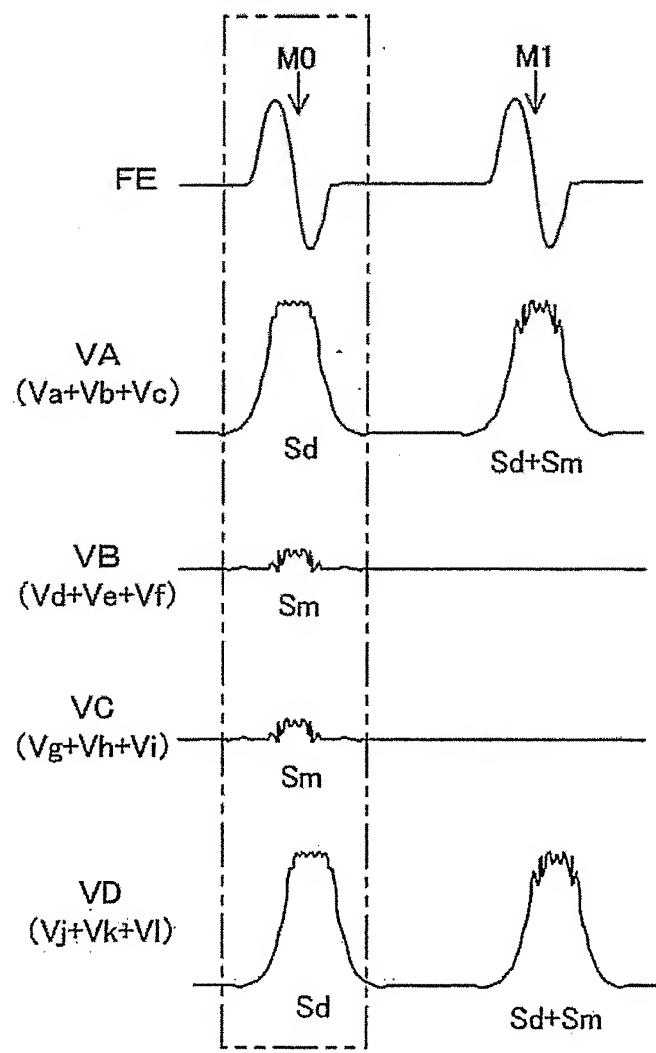


FIG.32C



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FIG.33A

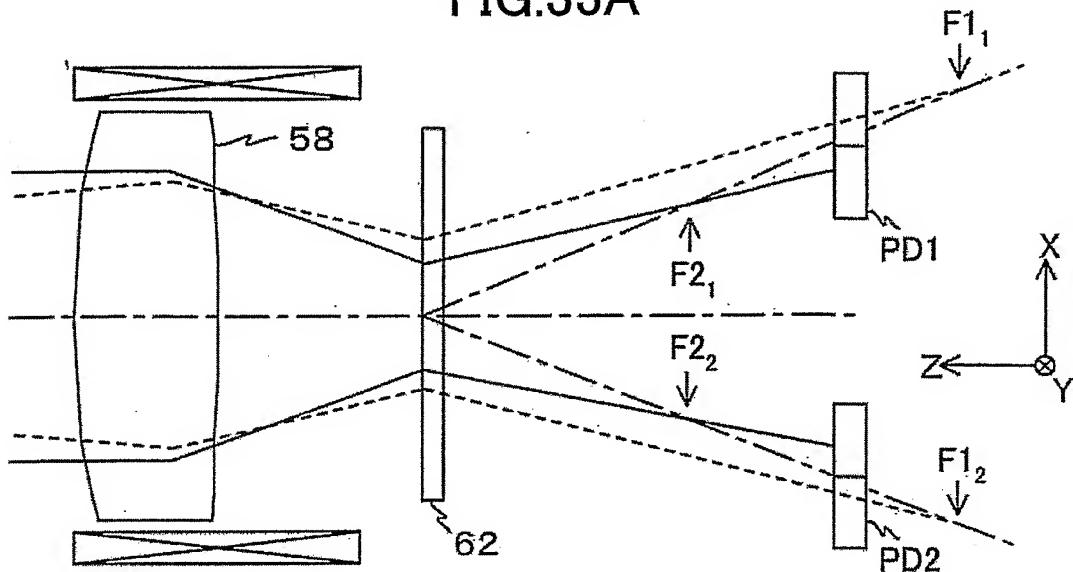


FIG.33B

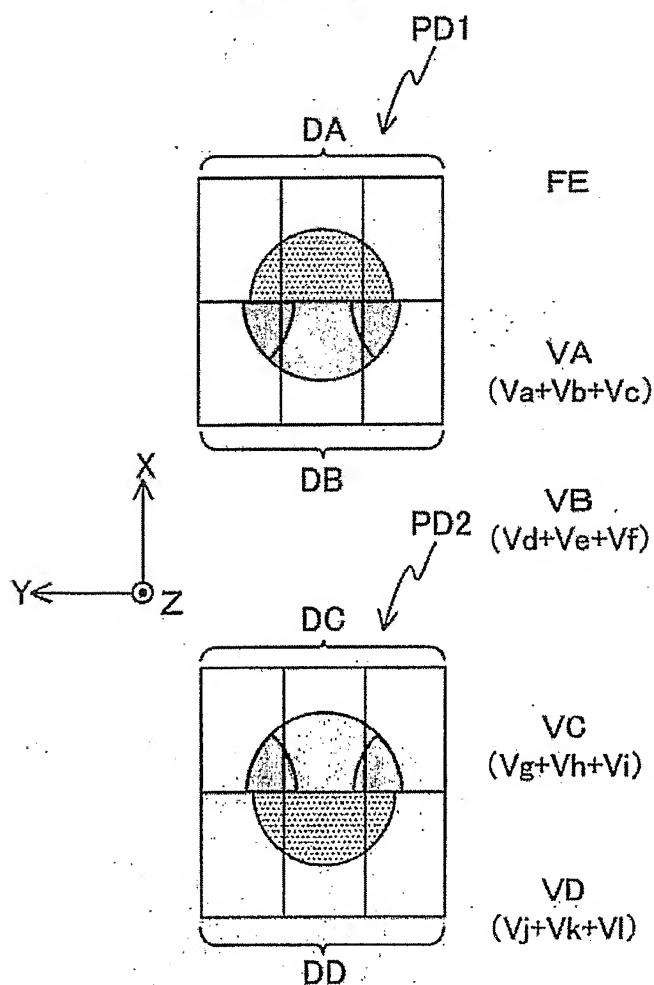
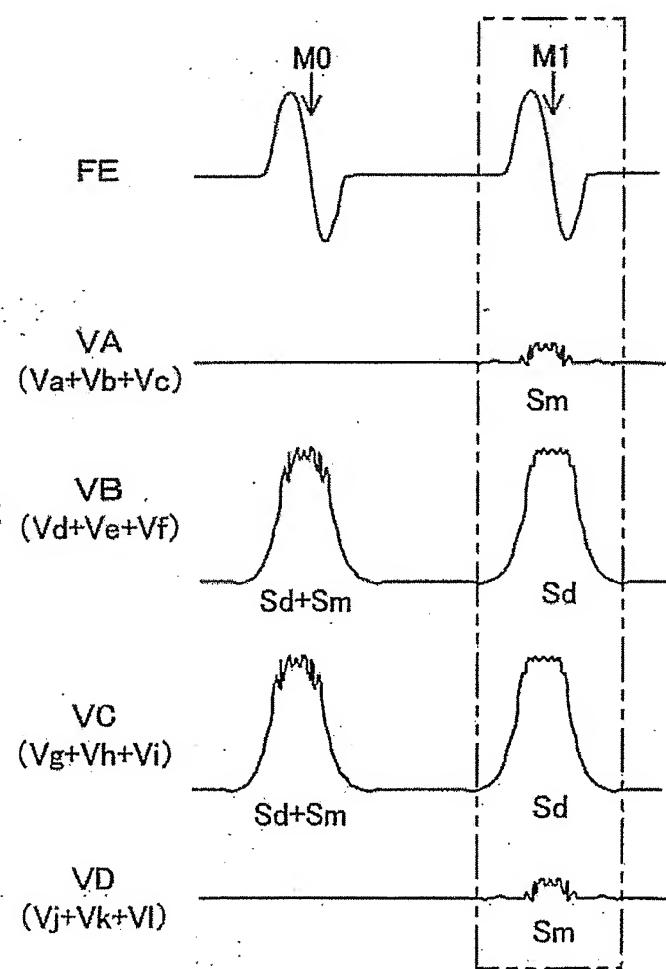
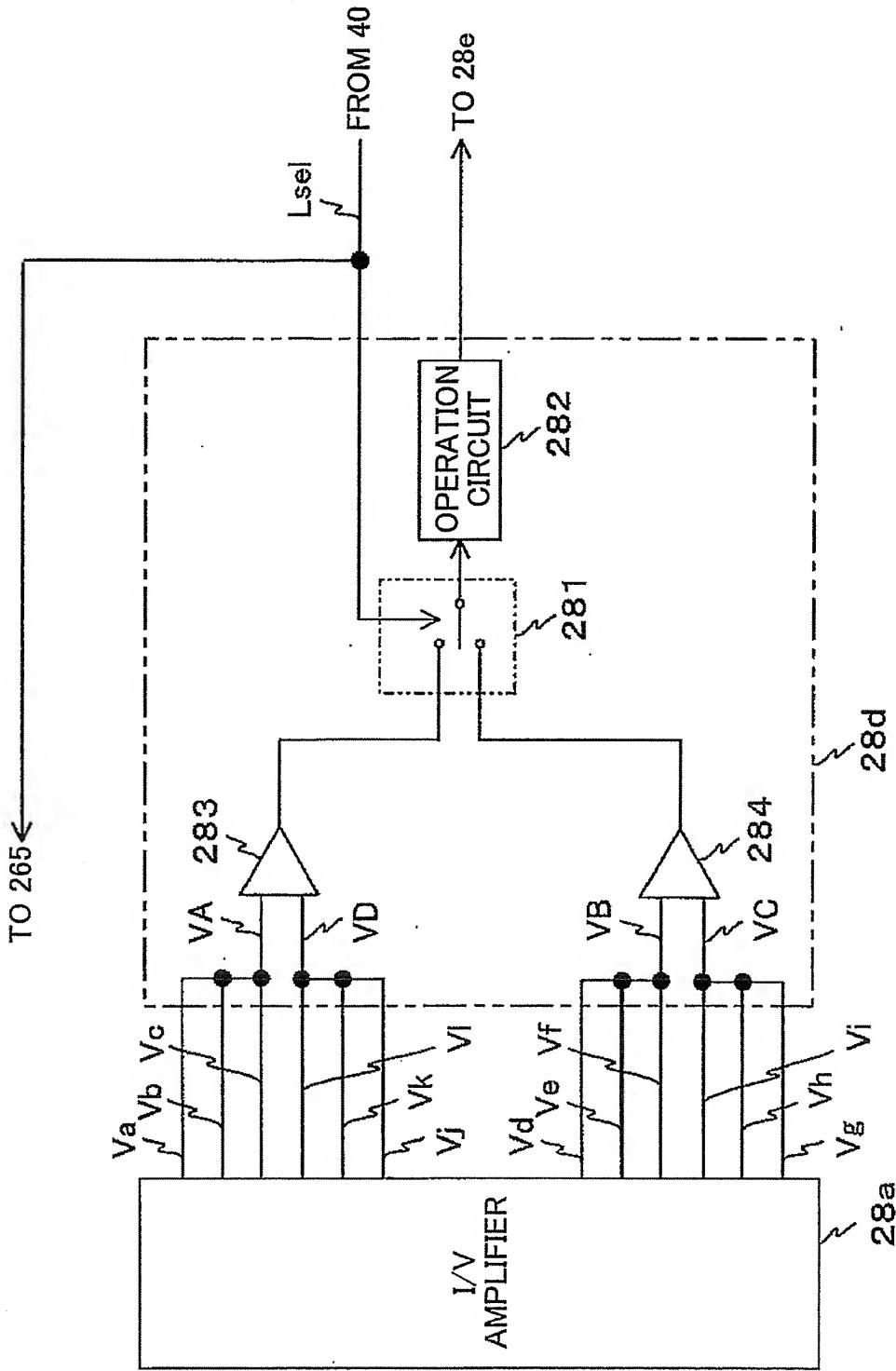


FIG.33C



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FIG.34



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FIG.35A

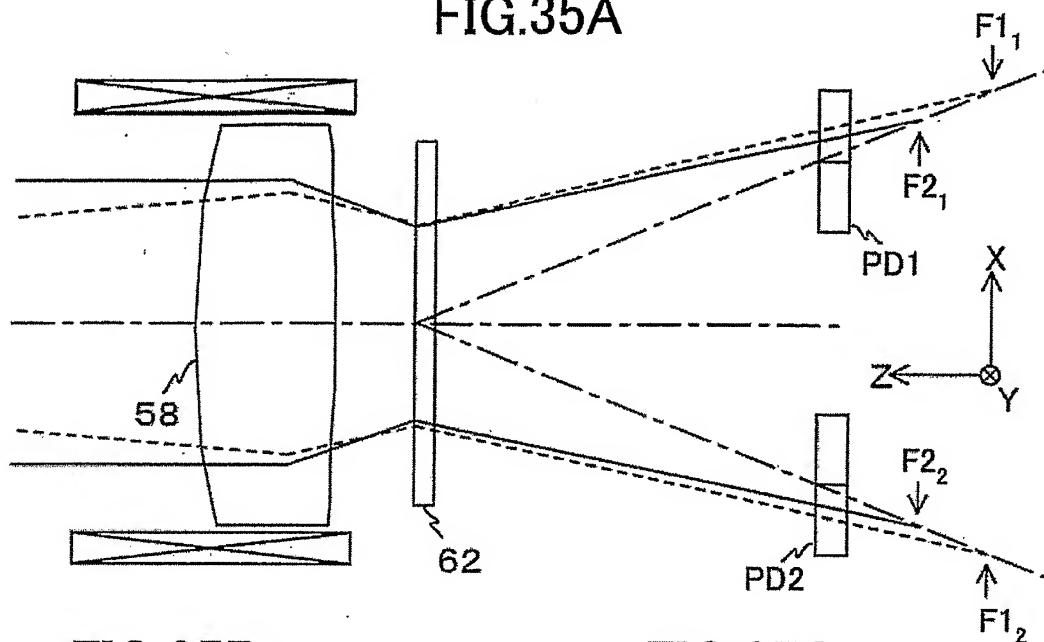


FIG.35B

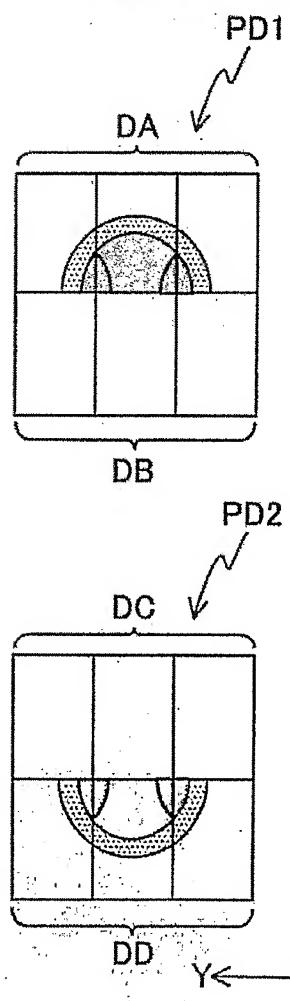
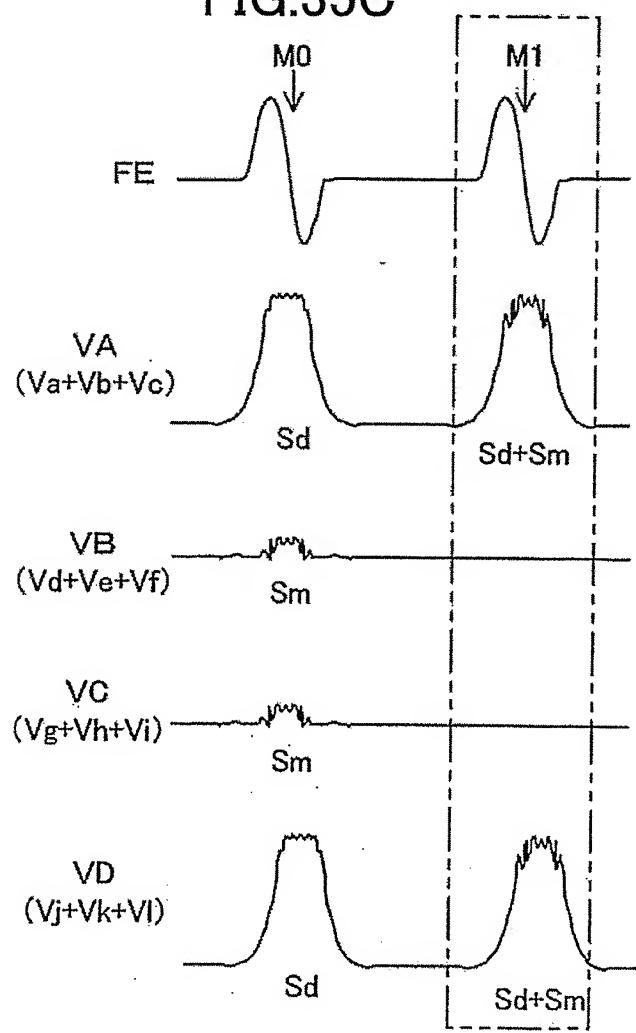


FIG.35C



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FIG.36A

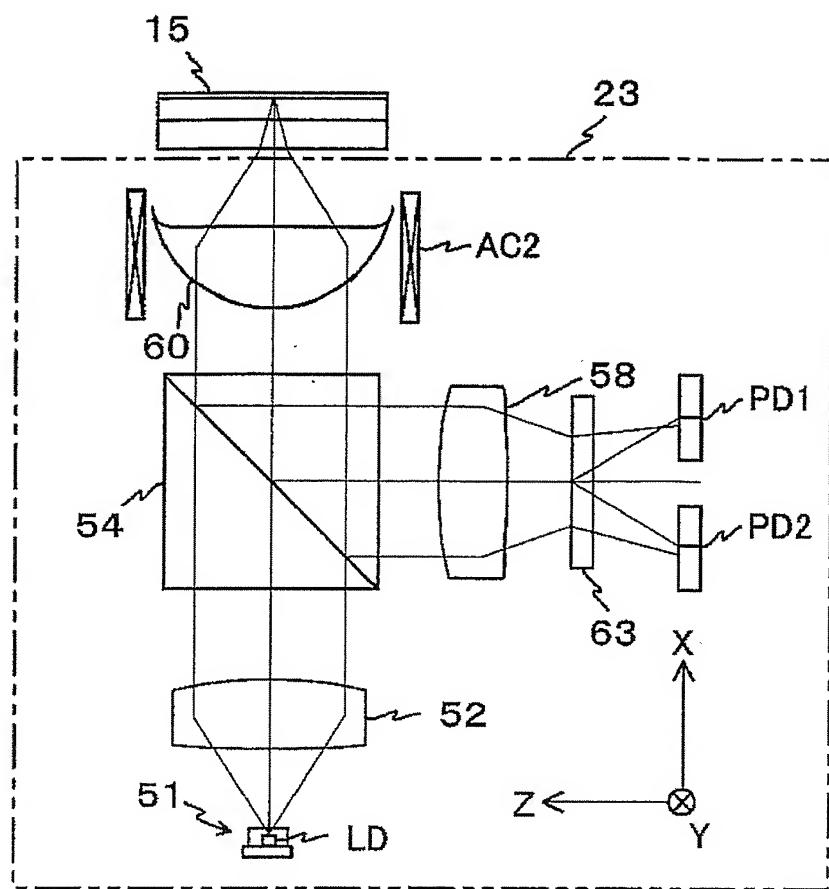
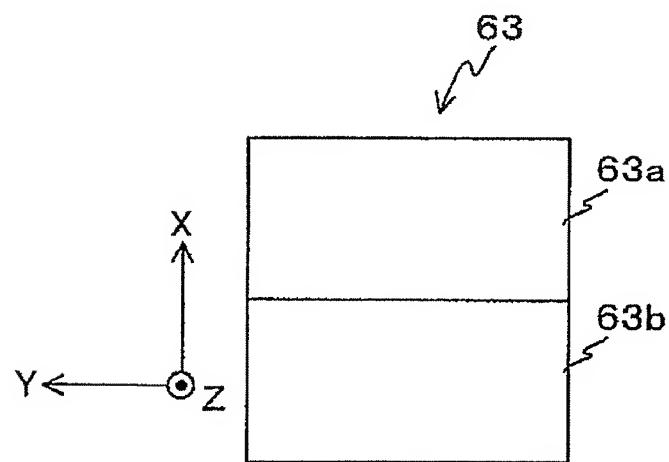


FIG.36B



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FIG.37A

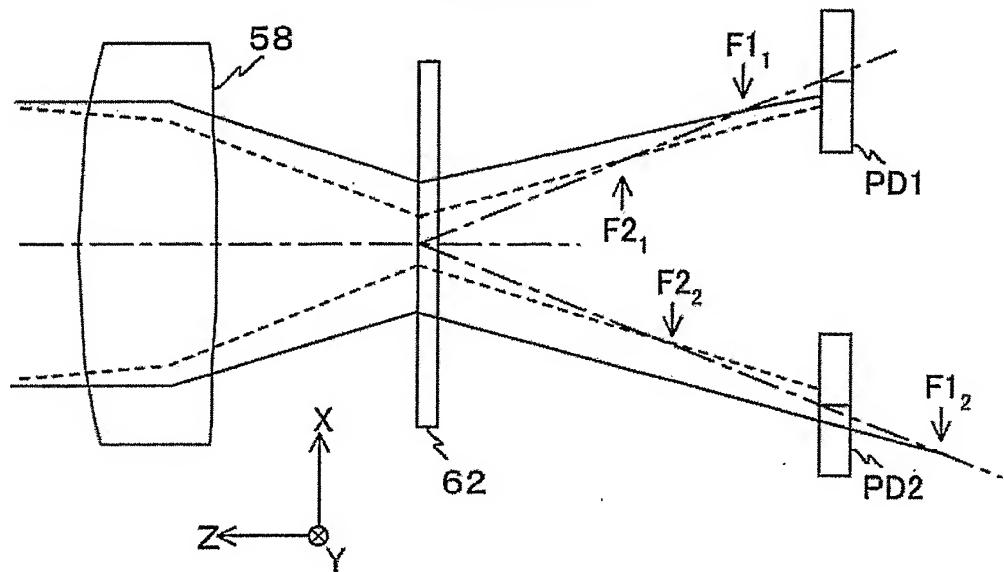


FIG.37B

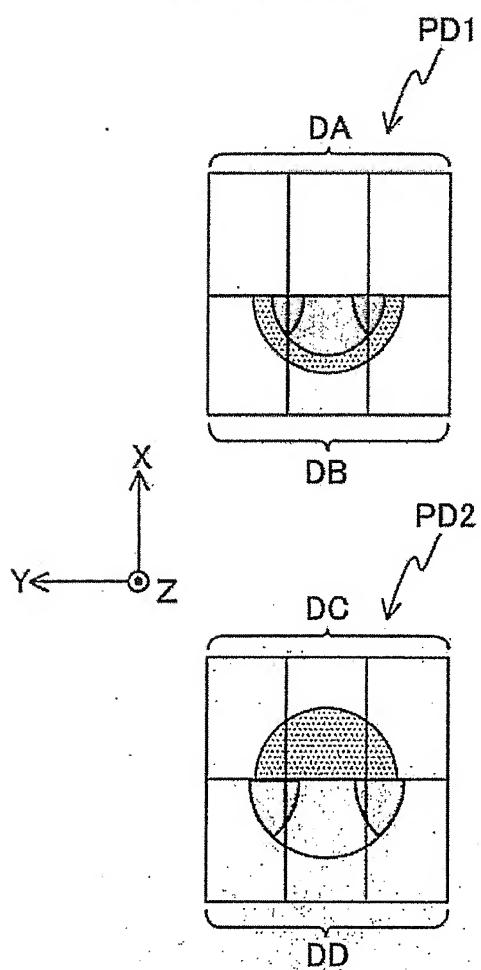
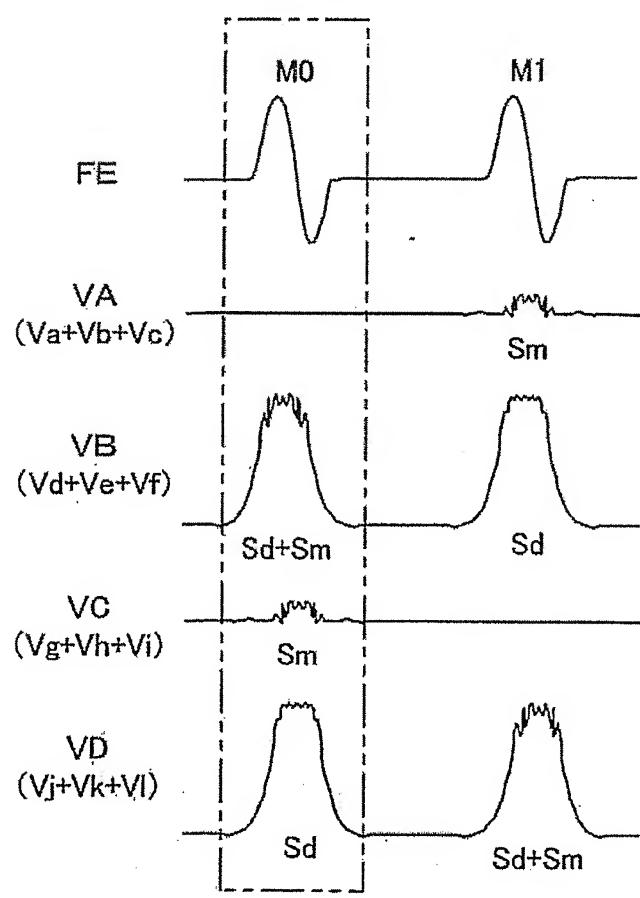


FIG.37C



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FIG.38A

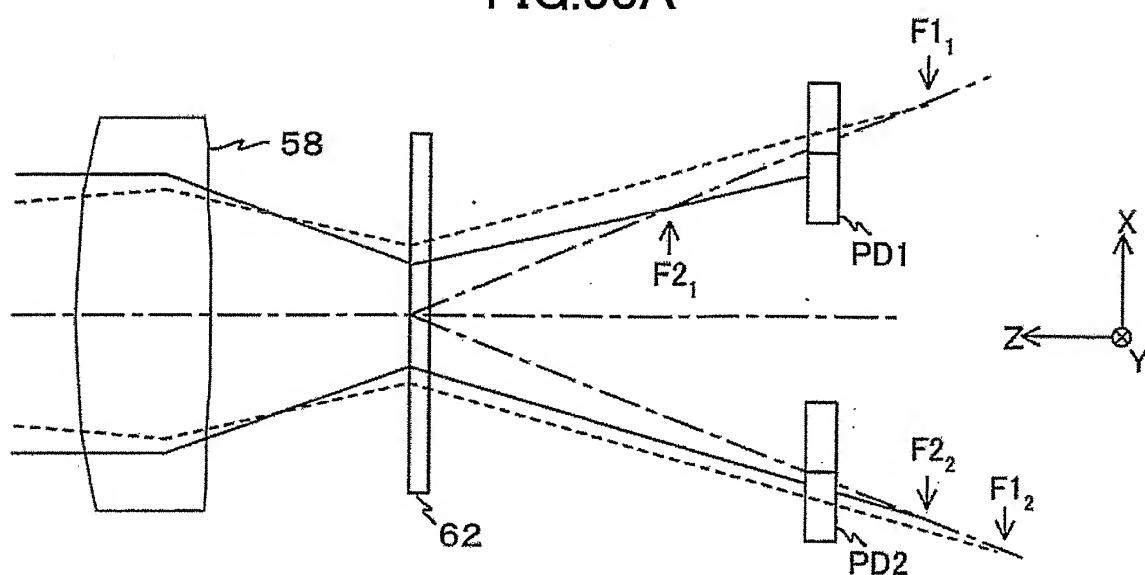


FIG.38B

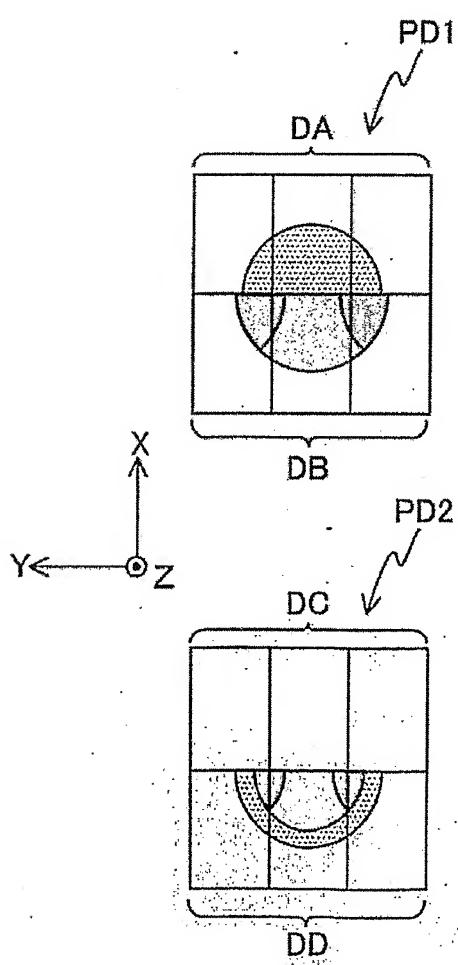


FIG.38C

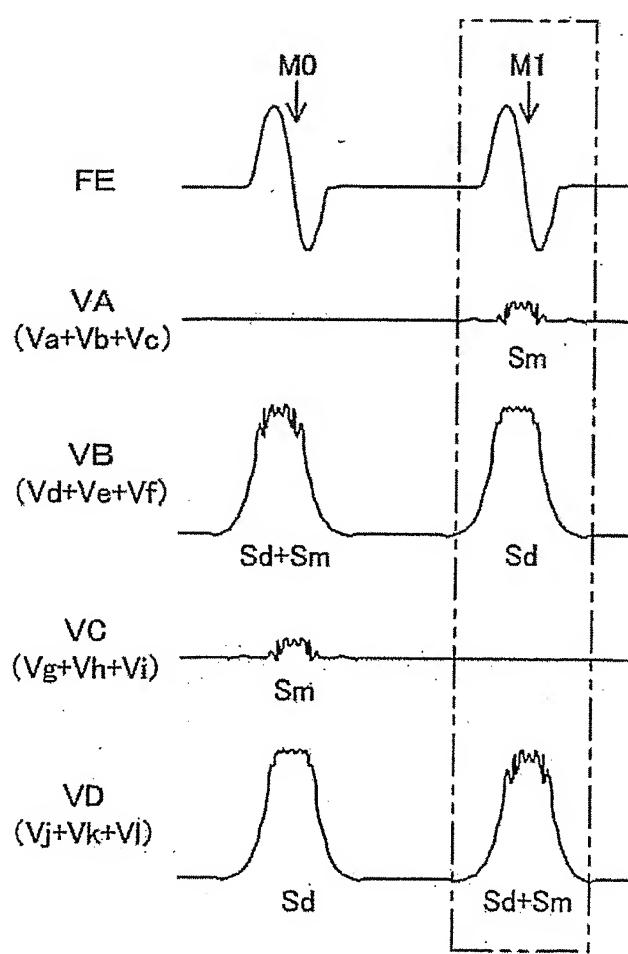
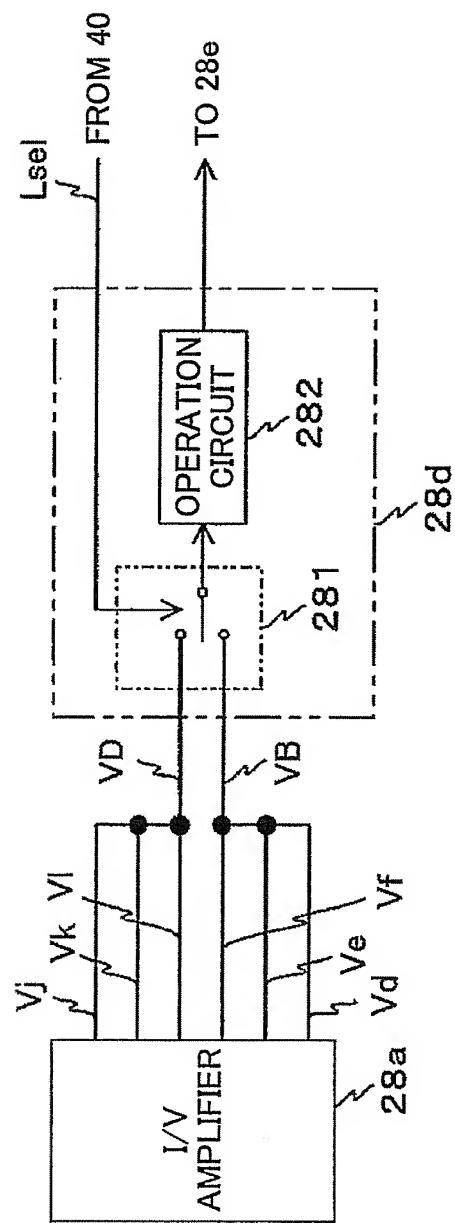


FIG.39



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FIG.40A

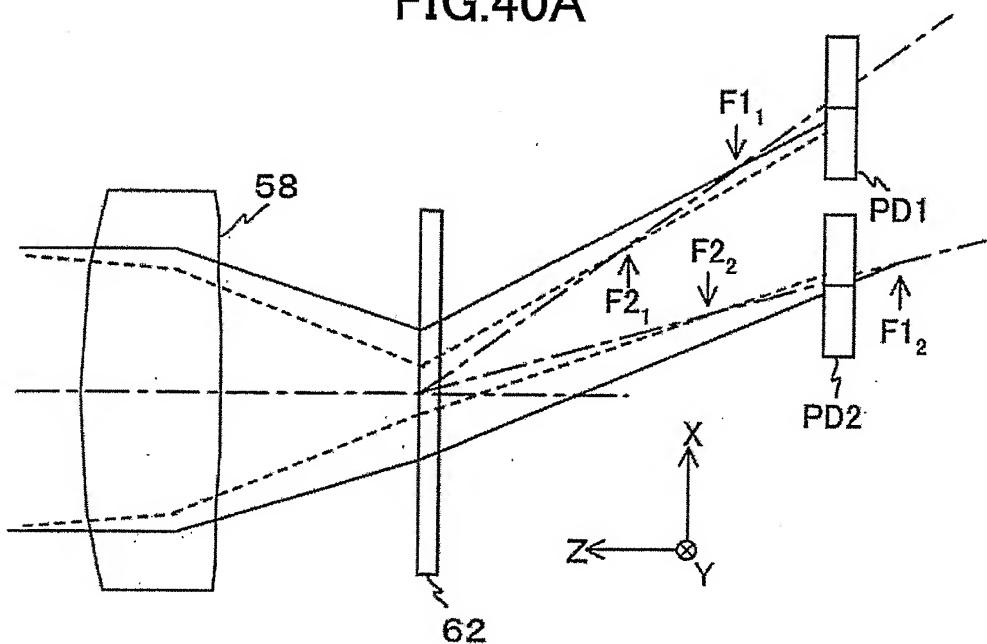
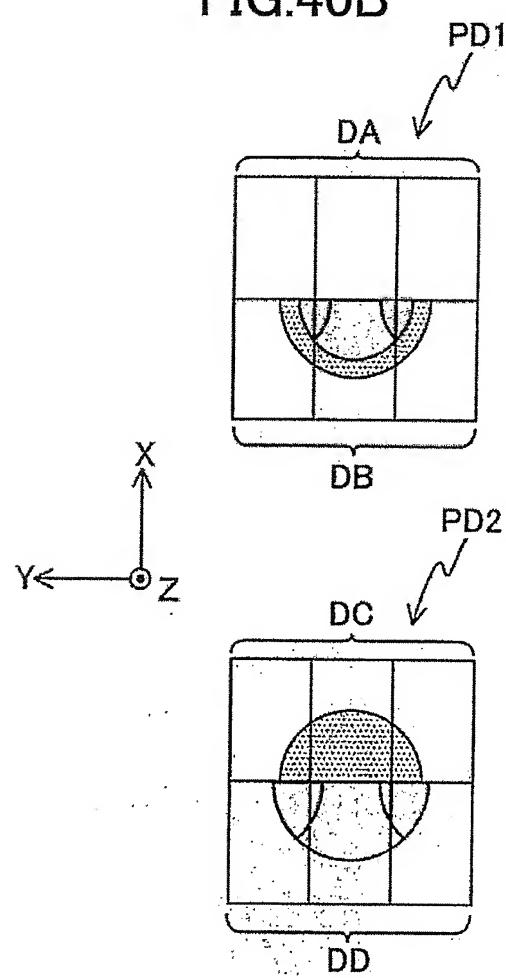


FIG.40B



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FIG.41A

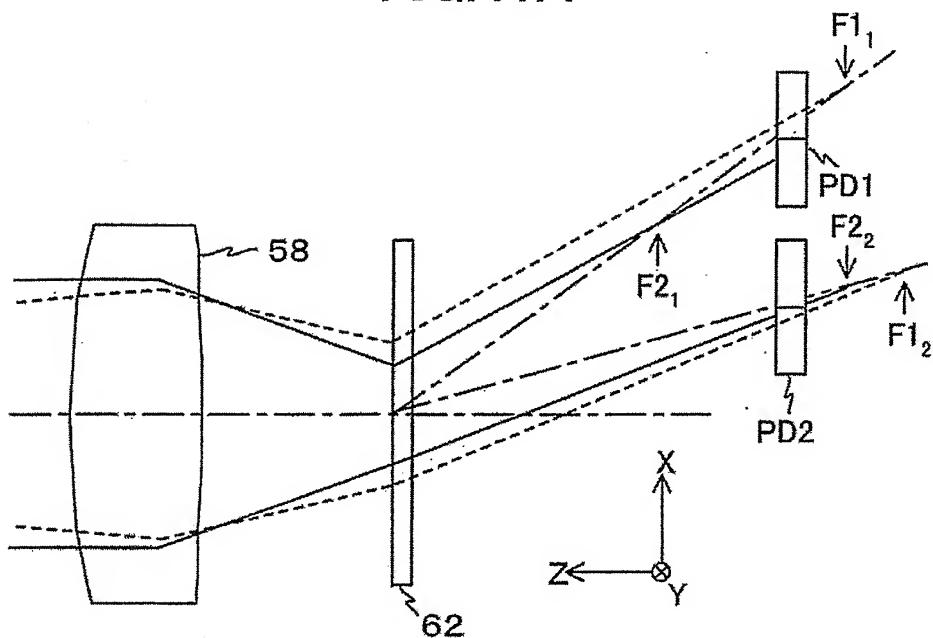
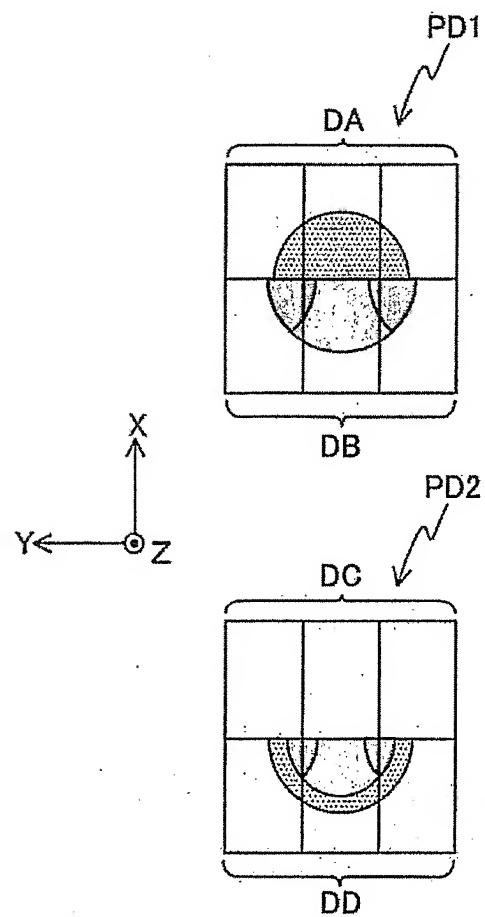


FIG.41B



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/002362

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl.⁷ G11B7/135, 7/005

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl.⁷ G11B7/135, 7/005

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
 Published unexamined utility model applications of Japan 1971-2005
 Registered utility model specifications of Japan 1996-2005
 Published registered utility model applications of Japan 1994-2005

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 62-192939 A (NEC Corporation) 24 Aug. 1987 (24.08.1987) 14 - 19 line on the lower left-hand section in page 1, figure 2 (family none)	1 - 19
A	JP 11-242824 A (Pioneer Ltd.) 7 Sep. 1999 (07.09.1999) paragraph number 0019 - 0023, figure 5 - 8 & US 6442125 B1	1 - 19
A	JP 2002-298345 A (Ricoh Ltd.) paragraph number 0004, 0008, figure 1 - 2 (family none)	1 - 19

 Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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 "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
 "&" document member of the same patent family

Date of the actual completion of the international search 22.06.2005	Date of mailing of the international search report 12.7.2005
Name and mailing address of the ISA/JP Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Authorized officer Yoshikawa Jun Telephone No. +81-3-3581-1101 Ext. 3551

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